Appendix A2

**Screening of Contaminants to Aquatic
and Terrestrial Resources**

A2–1.0 Introduction

Environmental consequences to aquatic and terrestrial species near the Moab site northwest of Moab, Utah, were assessed using data collected to estimate contaminant concentrations in the surface waters of the nearshore environment adjacent to and immediately downstream of the tailings pile. Contaminant data from the freshwater aquifer that underlies the tailings pile were also used to understand the source of contaminants in the surface water.

The assessment involved determining which contaminants of potential concern exceed detection limits and background samples, assessing the relevance of the sample location to biotic exposure, and comparing the contaminant concentrations to ecotoxicological screening benchmarks. Environmental consequences to aquatic biota are discussed first, followed by terrestrial biota.

Results of this assessment are used to support the BA of federally listed threatened and endangered species (Appendix A1). However, the species evaluated here are relatively common species of wildlife and fish for which toxicological benchmarks were available. Similar toxicity data are generally not available for threatened and endangered species. Consequently, in cases where threatened or endangered species may be exposed to contaminants, the BA utilizes species evaluated here as surrogates.

Results of this assessment are also used to support alternative evaluations of environmental consequences in Chapter 4.0 of the EIS.

A2–1.1 Screening of Contaminant Data for Aquatic Biota Assessment

The aquatic environment at the Moab site is mainly associated with the Colorado River. The Moab site is a former uranium-ore processing facility located on the west bank of the Colorado River at the confluence with Moab Wash, an ephemeral stream that runs from the northwest to the southeast, bisecting the site (Figure A2–1). The wash is adjacent to or near the eastern edge of the tailings pile on the site. The tailings pile and other decommissioned facilities on the site are the source of chemical contamination discharging into the Colorado River.

There are two principal plumes in the ground water from past activities at the Moab site: the millsite area plume, and the tailings area plume. The millsite plume is contaminated from mill wastes buried near the river upstream of the Moab Wash. The tailings area plume moves contaminants to the ground water from leachate that comes from the pile. The primary exposure route for contaminants to the aquatic environment is through the ground water.

The analysis for screening of contaminants for impacts to aquatic biota is divided into chemical and radiological impacts. Chemical contaminants have toxicological effects based on the activity of the contaminant in the organism. Radiological impacts have effects based on the energy released from the radioisotope when the organism uptakes that element. A contaminant may have both a chemical and radiological impact.

n:\moa\999\0005\02\012\x00331\x0033100.apr r50329 3/20/2003, 13:41   X0033100-07

Figure A2−1. Aerial view of the Moab site in 2001 identifying the locations of the tailings pile, Moab Wash, Colorado River, upstream background sampling location, and the Matheson Wetlands Preserve

Chemical Impacts. The aquatic environment near the site has been characterized (Chapter 3.0). Monitoring programs have included sampling sediment, fish tissue, and surface water near the Moab site and upstream environment. Sediment samples of the Colorado River were collected from 1995 through 1997; however, those samples were not considered in this analysis based on comments in the Final Biological Opinion in NRC's final EIS (NRC 1999) concerning the quality of the data for evaluation of impacts. Concerns for the quality of the sediment data include inappropriate procedures and protocols for sample collection and inadequate collection of samples for statistical evaluation. Fish were collected for tissue analyses from 1995 through 1997, and the fish tissue samples also were not considered in this analysis based on comments of data quality similar to those made about sediment samples in the Final Biological Opinion of NRC's final EIS (NRC 1999). Based on an evaluation of the means and standard deviation for all the combined fish tissue data, the results do not show a strong statistical difference in concentrations in the tissues collected upstream of the Moab site compared to those collected downstream.

The screening of contaminants presented in this section is based on surface water samples collected by SMI, DOE, and USGS. Samples were collected by SMI and DOE from 2000 through 2002. These data are presented in Appendix D of the *Site Observational Work Plan for the Moab, Utah, Site* (SOWP) (DOE 2003). USGS collected water sample data from 1998 through 2000; these data are presented in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002). Many of the samples from other studies were considered, but quality issues were discovered during data evaluation.

These issues included insufficient information to determine the location of the analyzed sample and laboratory quality control and quality assurance questions. Contaminants of potential concern for the Moab site were identified from institutional knowledge about the uranium milling processes used during operation of the Atlas mill, the NRC EIS (NRC 1999), and the Notice of Intent for this EIS published in the *Federal Register* (67 FR 77969 [2003]). Surface water monitoring data were evaluated to determine if estimated concentrations were above detection limits, background levels, and federal and state criteria for surface water quality (i.e., benchmarks) (Figure A2–2). Data on background ground water samples were taken from information provided in Chapter 5.0 and Appendix C of the SOWP (DOE 2003).
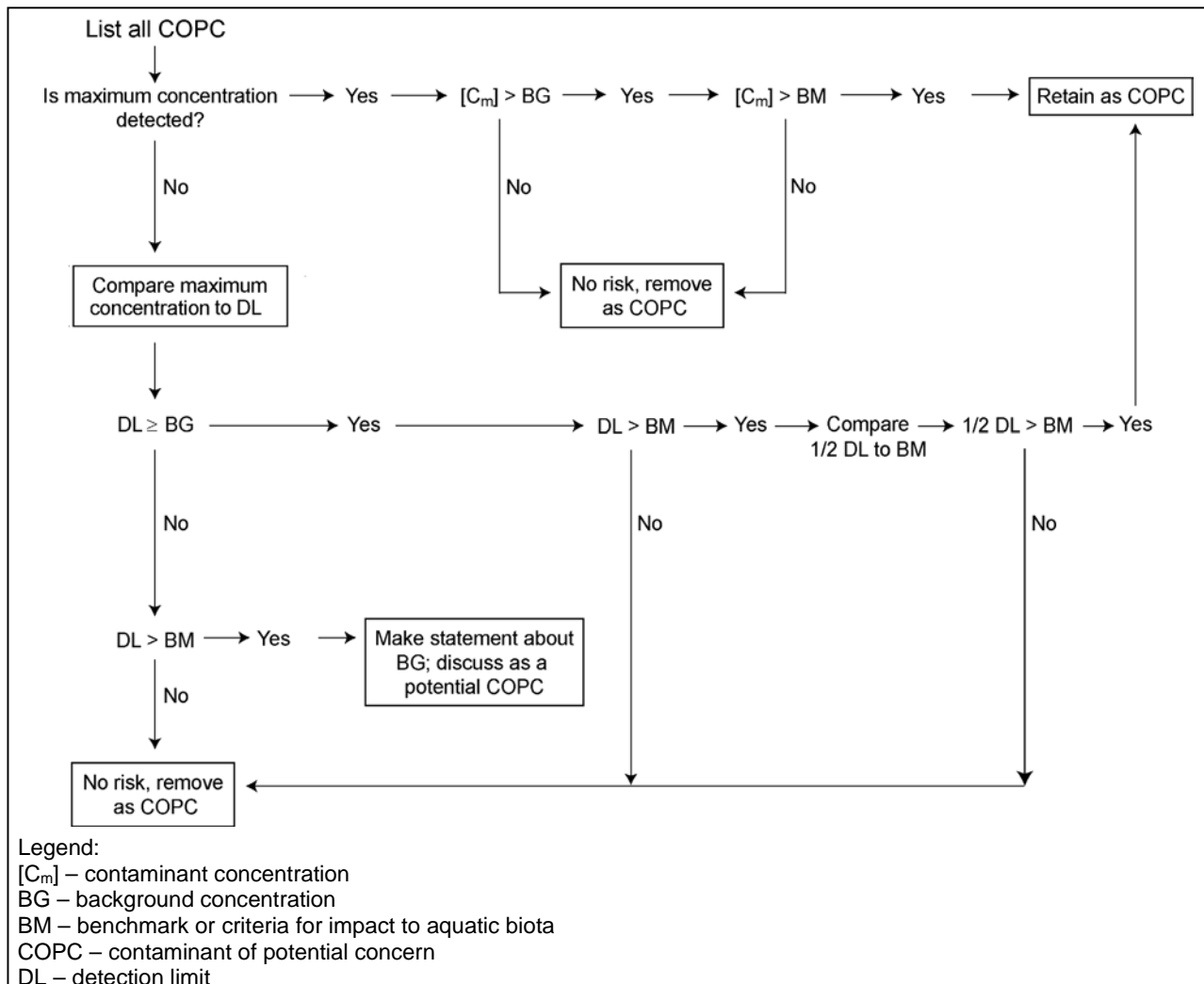

Figure A2–2. Evaluation of Contaminants of Potential Concern for Chemical Impacts to Aquatic Biota at the Moab Site

The 2000 through 2002 chemical constituent surface water data set was examined first to determine which sample results exceeded the detection limit set by the laboratory (Figure A2–2). If an analyte was not detected, the laboratory reported a value equal to the method detection limit. Analytes not detected were assessed using values corresponding to one-half the method detection limit, based on EPA protocol (EPA 2001a, 2001b). The maximum concentration for the contaminant at any location or time was then compared to the maximum background

concentration (Table A2–1). Two upstream locations were considered as background stations for the Moab site. These background stations were within 15 ft of each other (see Figure A2–1). If a given contaminant was not detected in any background sample, then one-half the reported detection limit was used in the evaluation. Finally, the maximum concentration above background was compared to benchmarks for evaluating impacts to aquatic biota (Table A2–2).

Benchmarks for the contaminants at the Moab site included the NWQC (EPA 2002) and proposed State of Utah water quality criteria (UAC 2003). Water quality standards are the foundation of a water-quality-based control program. Standards are mandated by the Clean Water Act (33 U.S.C. 1251 et seq.). Water quality standards define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. Utah's water quality standards are applicable to "waters of the State." Utah water quality standards apply to all waters within the state, with the exception of those waters that are within Indian Country, as defined in 18 U.S.C. Section 1151. Thus, the standards set for Utah, including the federal standards, were used for this assessment. However, the contaminants of potential concern included contaminants for which neither federal nor state criteria are established; therefore, criteria established by Suter and Tsao (1996) for aquatic biota were used. Suter and Tsao (1996) provide a compilation of aquatic toxicity values, including National Ambient Water Quality Criteria, derived Tier II values (secondary chronic and acute values), and chronic values from a variety of other government sources.

Impacts to aquatic organisms can result from either acute or chronic exposures to contaminants of potential concern. An acute exposure is defined as "the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect" (EPA 2002). A chronic exposure is defined as "the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect" (EPA 2002). Currently, the State of Utah criteria include an acute, 1-hour exposure and a chronic, 4-day exposure. As mentioned above, Suter and Tsao (1996) were used where state and federal standards were not available. However, they used a method, referred to as Tier II, to establish criteria for aquatic benchmarks using a smaller data set than required by EPA in the NWQC. Also, they developed estimated lowest chronic values for fish extrapolated from laboratory studies. Therefore, the standards from Suter and Tsao (1996) can be overly conservative and could not always be used for this analysis. These limits are discussed within the constituent-by-constituent discussions that follow.

The 2000 through 2002 surface water data were compared to the ecotoxicological screening benchmarks (Table A2–3). This comparison further pared the list of contaminants of potential concern for assessing potential impacts to aquatic biota. Contaminants were not considered further when (1) the maximum concentration and maximum background concentration were below detection and below all benchmarks, and (2) the maximum concentration was less than all the benchmarks (Table A2–3). The contaminants that were retained were further evaluated based on the number of samples, location of the samples, and the relevance of the flow regime at the time of sampling in comparison to the potential for exposure to aquatic biota.

Table A2–1. Minimum, Maximum, Background Range, Total Number of Samples, and Number of Samples Above Detection Limit for Contaminants of Potential Concern at the Moab Site, Utah (2000–2002 data)

Contaminant of Potential Concern	Minimum Concentration (mg/L)	Maximum Concentration (mg/L)	Background Concentration Range (mg/L)	Total Number of Samples	Number of Samples above Detection Limit
Aluminum	0.005	0.348[a]	0.008–0.14	182	84
Ammonia[b]	0.05	1440	0.05–0.134	266	266
Antimony	<0.001	0.0005[c]	0.0005[c]	62	0
Arsenic	<0.006	0.002[d]	<0.0006–0.002	71	42
Barium	0.002	0.211	0.051–0.14	186	185
Beryllium	<0.0001	0.00005[c]	0.00005[c]	3	0
Bismuth	<0.001	0.0005[c]	0.0005[c]	3	0
Boron	0.064	1.74	<0.0801–0.123	76	65
Cadmium	<0.0001	0.004	<0.00005[c]	114	11
Chloride	22	17300	25–172	301	301
Chromium	<0.0005	0.0005[c]	<0.0005–<0.0013	62	1
Copper	<0.00049	0.051[a]	<0.0006–<0.0014	182	61
Gross Alpha	1.1	665.45	7.31–13.82	93	
Iron	<0.003	7.23	0.0075–4.17	119	73
Lead	<0.0008	0.0005[c]	0.00005[c]	104	0
Lithium	0.0552	0.31[d]	0.057[d]	18	15
Manganese	0.0005	12	<0.003–0.076	260	147
Mercury	<0.0002	0.002[a]	0.00005[c]	96	1
Molybdenum	<0.001	1.91	<0.0028–0.007	290	275
Nickel	<0.0006	0.052	<.0006–0.002	56	19
Nitrate	0.829	21.7	1.86–5.51	76	75
pH	6.83	8.89	7.38–8.6	423	NA
Selenium	<0.0005	0.026	0.0013–0.0079	216	206
Silver	<0.00005	0.0025[c]	0.000025–0.00005[c]	63	0
Strontium	0.005	10.2	0.965–1.63	136	133
Sulfate	72	14400	84.1–439	301	290
Thallium	<0.001	0.0005[c]	0.0005[c]	63	21
Uranium	0.0013	5.12	0.0023–0.008	331	331
Vanadium	0.0003	0.249	0.00073–0.0031	148	132
Zinc	<0.0008	0.023	<0.0017–0.006	112	50

[a]Analyte is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]All analytes were below detection; maximum value based on one-half of detection limit.
[d]Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.

Table A2–2. Chemical Benchmarks for Assessing Potential Impacts to Aquatic Organisms From Inorganic Contaminants of Potential Concern at the Moab Site, Utah (2000–2002 data)

Contaminant of Potential Concern	National Recommended Water Quality Criteria[a]		Utah State Water Quality Criteria[b]		Suter and Tsao (1996)		
	Acute	Chronic	Aquatic Wildlife 3B-Acute	Aquatic Wildlife 3B-Chronic	Tier II Acute	Tier II Chronic	Lowest Chronic
Milligrams per liter (mg/L) unless otherwise noted							
Aluminum	0.75[c]	0.087[c]	0.75[c]	0.087[c]			3.288
Ammonia	[d]	[e]	[d]	[e]			1.7
Antimony					0.18	0.03	1.6
Arsenic	0.34[g]	0.15[g]	0.34[f,g]	0.15[f,g]	0.066	0.0031	0.892
Barium					0.11	0.004	
Beryllium					0.035	0.00066	0.057
Bismuth							
Boron					0.03	0.0016	
Cadmium	0.002[g,h]	0.00025[g,h]	0.0039[g,h]	0.0011[g,h]			0.0017
Chloride	860	230					
Chromium[i]	0.016[g]	0.011[g]	0.016	0.011			0.07318
Copper	0.013[g,h]	0.009[g,h]	0.018[g,h]	0.012[g,h]			0.0038
Gross Alpha			15 pCi/L	15 pCi/L			
Iron[j]		1	1	1			1.3
Lead	0.065[g,h]	0.0025[g,h]	0.082[g,h]	0.0032[g,h]			0.01888
Lithium					0.26	0.014	
Manganese					2.3	0.12	1.78
Mercury	0.0014[g]	0.00077[g]	0.0024	0.000012		0.0013	< 0.00023
Molybdenum					16	0.37	
Nickel	0.47[g,h]	0.052[g,h]	1.40[g,h]	0.16[g,h]			< 0.035
Nitrate			4	4			
pH			6.5–9.0	6.5–9.0			
Selenium		0.005[k]	0.0184[g]	0.0046[g]			0.08832
Silver	0.0032[g,h]		0.0041[g,h]			0.00036	0.00012
Strontium					15	1.5	
Sulfate							
Thallium					0.11	0.012	
Uranium					0.046	0.0026	0.142
Vanadium					0.28	0.02	0.08
Zinc	0.12	0.12	0.12	0.12			0.03641

[a]National Recommended Water Quality Criteria are based on EPA 2002 except for ammonia, which is based on EPA 1999.
[b]Changes and updates to the Utah State Water Quality Standards as of November 2003 (UAC 2003).
[c]Aluminum is expressed in terms of total recoverable metal in the water column.
[d]Refer to EPA 1999 and UAC 2003 for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e]Refer to EPA 1999 and UAC 2003 for calculation of pH, temperature, and life-stage-dependent chronic ammonia benchmarks.
[f]Arsenic values based on arsenic V.
[g]Criteria for metals are expressed in terms of dissolved metal in the water column.
[h]Criteria are expressed as a function of hardness. The value listed corresponds to a hardness of 100 mg/L.
[i]Chromium values based on chromium (VI).
[j]Criteria are for dissolved iron.
[k]Criteria for selenium are expressed in terms of total recoverable metal in the water column.

Contaminant of Potential Concern	Sample Location for Maximum Concentration	Maximum Concentration (in mg/L)	Number of samples above Acute NWQC Benchmark [a]	Number of samples above Chronic NWQC Benchmark [a]	Number of Samples above Utah Wildlife 3B-Acute Benchmark [b]	Number of Samples above Utah Wildlife 3B-Chronic Benchmark [b]	Number of samples above Acute Tier II Benchmark [c]	Number of samples above Chronic Tier II Benchmark [c]	Number of samples above Lowest Chronic Benchmark [c]	Comments on Contaminant of Potential Concern
Aluminum	CR2-BX	0.348 [d]	0	2	0	2	NA	NA	0	Measured Concentration above background and NWQC chronic benchmark. Background above Chronic Tier II. Retain as COPC.
Ammonia	CR2-BX	1440	[e]	[f]	[e]	[f]	NA	NA	[f]	Measured concentrations above background and benchmarks. Retain as COPC.
Antimony	NA	0.0005 [g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Arsenic	CR2-BX	0.002 [h]	0	0	0	0	0	0	0	Two samples above detection limit and background. Measured concentration below all benchmarks. Not retained at COPC.
Barium	Moab Wash	0.211	NA	NA	NA	NA	4	4	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Acute and Chronic Tier II. Retain as COPC.
Beryllium	NA	0.00005 [g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Bismuth	NA	0.0005 [g]	NA	NA	NA	NA	NA	NA	NA	Measured concentration and background are below detection limits. Measured concentration detection limit is the same as the background detection limit. Not retained as COPC.
Boron	0206	1.74	NA	NA	NA	NA	9	9	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Acute and Chronic Tier II. Retain as COPC.
Cadmium	CR2BX	0.004	3	10	1	4	NA	NA	3	Measured concentration above background and multiple acute and chronic benchmarks. All background is below detection limit. Half detection limit for background samples is below all benchmarks. Retain as COPC.
Chloride	0206	17300	13	13	NA	NA	NA	NA	NA	Measured Concentration above background and NWQC acute and chronic benchmark. Retain as COPC.
Chromium	NA	0.0005 [g]	0	0	0	0	NA	NA	0	Measured concentrations below detection limit and below background. Not retained as COPC.
Copper	CR2-BX	0.051 [d]	9	16	5	9	NA	NA	21	Measured concentration above background and multiple acute and chronic benchmarks. Retain as COPC.
Iron	CRD	7.23	NA	13	13	13	NA	NA	13	Measured Concentration above background and all benchmarks. Background above all benchmarks. Retain as COPC.
Lead	NA	0.0005 [g]	0	0	0	0	NA	NA	0	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Lithium	CR2B	0.31 [h]	NA	NA	NA	NA	1	11	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Chronic Tier II. Retain as COPC.
Manganese	CR2B	12	NA	NA	NA	NA	10	15	10	Measured concentration above background and all benchmarks. Retain as COPC.

[a] NWQC (National Recommended Water Quality Criteria) is based on EPA 2002 except for Ammonia, which is based on EPA 1999.
[b] Utah State Water Quality Criteria is based on UAC 2003.
[c] Suter and Tsao, 1996
[d] Refer to references for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e] Refer to references for calculation of pH, temperature and life-stage-dependent chronic ammonia benchmarks.
[f] Analyte is estimated, based on laboratory qualifier.
[g] All analytes were below detection; maximum value based on one-half of detection limit.
[h] Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.

Contaminant of Potential Concern	Sample Location for Maximum Concentration	Maximum Concentration (in mg/L)	Number of samples above Acute NWQC Benchmark[a]	Number of samples above Chronic NWQC Benchmark[a]	Number of Samples above Utah Wildlife 3B-Acute Benchmark[b]	Number of Samples above Utah Wildlife 3B-Chronic Benchmark[b]	Number of samples above Acute Tier II Benchmark[c]	Number of samples above Chronic Tier II Benchmark[c]	Number of samples above Lowest Chronic Benchmark[c]	Comments on Contaminant of Potential Concern
Mercury	NA	0.002[f]	NA	NA	1	85	NA	1	1	One sample with a measured concentration above the detection limit, background and all benchmarks. Measured concentration in all other samples and background are below detection limits. Half detection limit is above Utah State Chromic wildlife benchmark. Retain as COC.
Molybdenum	CR2-BX	1.91	NA	NA	NA	NA	0	10	NA	Measured concentration above background and Tier II chronic benchmark. Retain as COC.
Nickel	CR2-BX	0.052	0	1	0	0	NA	NA	1	Measured concentration above background and NWQC chronic benchmark. Retain as COC.
Nitrate	CR2B	21.7	NA	NA	36	36	NA	NA	NA	Measured concentration above background and Utah State acute and chronic benchmark. Background above Utah State acute and chronic benchmark. Retain as COC.
Selenium	CR3-10	0.026	NA	7	1	7	NA	NA	0	Measured Concentration above background and above NWQC chronic benchmark and Utah State chronic and acute benchmarks. Background above NWQC chronic and Utah state chornic benchmarks. Retain as
Silver	NA	0.0025[g]	1	NA	1	NA	NA	2	33	Measured concentrations and background are below detection limit. Half detection limit for one sample is above Tier II chronic and lowest chronic benchmarks. Half detection limit in remaining samples and background are below all benchmarks. Retain as COC.
Strontium	CR3-001	10.2	NA	NA	NA	NA	0	19	NA	Measured concentration above background and Tier II chronic benchmark. Background above chronic Tier II. Retain as COC.
Sulfate	CR2-BX	14400	NA	NA	NA	NA	NA	NA	NA	Measured concentration above background. Retain as COC
Thallium	CRBA	0.0005[g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COC.
Thorium	CR4	1.7[i]	NA	NA	NA	NA	NA	NA	NA	Measured concentration is below background and all benchmarks. Not retained as COC.
Uranium	Moab Wash	5.12	NA	NA	NA	NA	42	263	16	Measured Concentration above background and above Tier II acute and chronic benchmarks and lowest chronic benchmark. Background above Tier II chronic benchmark. Retain as COC.
Vanadium	MWSeep	0.249	NA	NA	NA	NA	0	2	2	Measured concentration above background and above Tier II chronic and lowest chronic benchmarks. Retain as COC.
Zinc	CR2-BX	0.023	0	0	0	0	NA	NA	0	Measured concentration above background and below all benchmarks. Not retained as COC.

[a] NWQC (National Recommended Water Quality Criteria) is based on EPA 2002 except for ammonia, which is based on EPA 1999.
[b] Utah State Water Quality Criteria is based on UAC 2003.
[c] Suter and Tsao 1996
[d] Refer to references for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e] Refer to references for calculation of pH, tenperature and life stage dependent chronic ammonia benchmarks.
[f] Analyte is estimated, based on laboratory qualifier.
[g] All analytes were below detection; maximum value based on one-half of detection limit.
[h] Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.
[i] Analyte detected in both the sample and the associated blank.

Table A2−3. Comparison of Contaminants of Concern to Associated Benchmarks for Aquatic Biota at the Moab Site (page 2 of 2)

The 1998 through 2000 data summarized in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002) were also examined. Results presented in the USGS report indicate that the pile represents a localized source of ground water input containing elevated levels of contaminants, including copper, manganese, zinc, and radiochemicals. These contaminants were measured at levels that exceeded benchmarks during the low-water hydrologic period ranging from August through March. Based on the results of this study, USGS summary data for copper, manganese, zinc, and total alpha were evaluated using the process previously described (see Figure A2–2). These results are discussed where applicable within the constituent-by-constituent discussions that follow.

Toxicity of contaminants of potential concern is often related to water quality. The following discussions summarize water quality parameters that are considered in further discussions on the contaminants of potential concern.

Water Quality Parameters

pH. The measure of pH is an indicator of overall water quality. Aquatic organisms can be sensitive to large fluctuations in pH. However, gradual changes in pH may not affect organisms except to change the potential toxicity of other contaminants (e.g., ammonia). Twenty-nine surface water samples were collected at background locations; sample pH ranged from 7.38 to 8.6. Surface water samples near the Moab site had a pH between 6.83 and 8.89. The range of pH is within the State of Utah water quality criteria (UAC 2003). Continued monitoring of pH during the collection of surface water would be necessary to ensure protection of aquatic biota.

Temperature. Surface water temperature varies seasonally and diurnally, especially at low-flow conditions. There were 269 measures of temperature for surface water samples collected from 2000 to 2002. The temperature measurements ranged from 3.0 to 34.6 ^{o}C (37.4 to 94.3 ^{o}F). The maximum temperature for the Moab reach of the Colorado River was 27 ^{o}C (UAC 2003). Forty-two measurements along the shoreline near the tailings pile were above the standard for maximum temperatures. Most measurements were recorded during a 2-day period in July 2000; a few were made in April through August. The measurements were often in shallow pools along the edge of the river and islands in the river (e.g., CRBBY1; see locations in Figure A2–3). Continued monitoring of temperature during the collection of surface water samples would be necessary to ensure protection of aquatic biota.

Hardness. In general, hardness is a measure of the divalent metallic ions in surface water. The primary contributors to hardness are typically calcium and magnesium; however, the geological system can contribute other ions that are measured by a total hardness analysis. Hardness is related to the toxicity of many heavy metals; as hardness increases, the effect of the toxicity due to the metal decreases (EPA 2002). Examples of such metals include cadmium, copper, and nickel. USGS measured total hardness as part of its site-specific assessment of the effect of ammonia on endangered fish in the Colorado River adjacent to the Moab site. The measurements were made during three sampling events in September 1999, February 2000, and August 2000. The background locations had a range of total hardness from 140 to 700 mg/L as $CaCO_3$, and an average of 416 mg/L as $CaCO_3$. Total hardness as $CaCO_3$ in samples collected along the shoreline near the Moab site ranged from 320 to 512 mg/L and averaged 378 mg/L. Continued monitoring of hardness during the collection of surface water samples would be necessary to ensure protection of aquatic biota.

Total Dissolved Solids. Salinity alone can be toxic to many aquatic species. Total dissolved solids in excess of 15,000 mg/L are considered unsuitable for freshwater fish (NRC 1999). The toxicity of salinity depends on the ionic composition that produces the salinity (NRC 1999). Pimentel and Bulkley (1983) reported salinity concentrations that were avoided by juvenile Colorado pikeminnow, humpback chub, and bonytail. They found that Colorado pikeminnow avoided total dissolved solids above 4,400 mg/L, humpback chub avoided concentrations above 5,100 mg/L, and bonytail avoided concentrations above 6,600 mg/L. The background surface water concentration for total dissolved solids ranges from 430 to 1,060 mg/L (12 samples). Background ground water concentrations range from 677 to 97,014 mg/L total dissolved solids. The mean ground water concentration in the fresh Qal facies is 4,450 mg/L, and the mean concentration in the brine Qal facies is 51,400 mg/L. Concentrations of total dissolved solids in 29 of the 76 surface water samples collected near the Moab site were above the maximum background surface water concentration. Four of the 29 samples had concentrations that were above the levels found to cause avoidance behavior. The proposed State of Utah water quality standards (UAC 2003) provide for total dissolved solids in the surface water to be at background. Continued monitoring of total dissolved solids during active ground water remediation would be necessary to ensure protection of aquatic biota.

Contaminants of Potential Concern

The following is an evaluation of each contaminant of potential concern retained after the evaluation of surface water sampling results (Table A2–3).

Aluminum. Aluminum is a heavy metal with numerous valence states that vary according to the environment (e.g., pH and oxygen concentration). At a pH similar to that of Colorado River water near the Moab site (ranging from 6.8 to 8.9), aluminum is not very toxic to aquatic biota such as fish and amphibians (Hoffman et al. 1995). Aluminum was not detected in background ground water samples. Twelve background surface water samples were collected from 2000 to 2002 with values ranging from 0.008 to 0.14 mg/L (DOE 2003 and Chapter 3.0 of the EIS). Only two of 182 surface water samples had aluminum concentrations that exceeded the NWQC and State of Utah chronic benchmarks; the maximum background concentration also exceeded the State of Utah chronic benchmark. The State of Utah chronic criterion does not apply to waters with a pH equal to or greater than 7.0 and hardness equal to or greater than 50 mg/L as $CaCO_3$ in the receiving water after mixing. The pH and hardness values for Colorado River water near the Moab site indicate that aluminum is regulated by the acute aluminum criteria, which were not exceeded. Based on (1) the lower toxicity of aluminum in waters with high pH and hardness, (2) the low number of samples with aluminum concentrations that exceeded chronic benchmarks, and (3) the background surface water concentration, an acute or chronic effect resulting from aluminum only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to aluminum are small, and further assessment is not warranted.

Ammonia. Ammonia is a form of nitrogen that is highly toxic to aquatic biota. The toxicity of ammonia is related to the ammonia ionization, which is a function of pH and temperature. Ionized ammonia (NH_4^+) is not as toxic as the un-ionized form (NH_3) (Hoffman et al. 1995). Short exposures of fish to high concentrations of ammonia (acute conditions) can cause increased gill ventilation, hyperexcitability, convulsions, and death. These effects are likely a direct effect of ammonia on the central nervous system. Long-term exposure of fish to lower concentrations of ammonia (chronic conditions) can cause histological changes, decreased reproductive capacity, decreased growth and morphological development, and increased

susceptibility to disease in fish (Rand and Petrocelli 1985). Ammonia in the ground water at the Moab site is from operations associated with the extraction of uranium.

Concentrations of ammonia in surface water samples exceed acute and chronic benchmarks at numerous locations along the shoreline at the Moab site. Acute criteria for ammonia vary as a function of pH, and the chronic criteria for ammonia vary as a function of pH and temperature. The federal and state criteria are calculated on the basis of the presence or absence of salmonids (i.e., salmon or trout) and early life stages of fish. The most applicable calculations for ammonia and aquatic organisms in the Colorado River are for the absence of salmonids and the presence of early life stages of fish. Table A2–2 does not include numerical values for federal or state criteria because the benchmark for ammonia can vary greatly according to temperature and pH, which can change dramatically during even a 1-day period. Temperature and pH measurements taken simultaneously with samples for ammonia analysis from 2000 to 2002 produced federal acute criteria that ranged from 1.06 to 39.0 mg/L total ammonia. The same process resulted in federal chronic criteria that ranged from 0.29 to 5.34 mg/L total ammonia. Further information on the calculation of ammonia criteria is discussed in Appendix D of the SOWP (DOE 2003). Figure A2–3 shows the distribution of total ammonia in the surface water at the Moab site.

USGS conducted a site-specific risk assessment to determine if ground water entering the Colorado River from beneath the tailings pile could affect the endangered Colorado pikeminnow and razorback sucker (USGS 2002). Results indicate that during the low-flow period from August to March, ammonia levels exceed State of Utah standards. The area of contamination varies with hydrologic regime but in general is confined to an area less than 6,000 square yards (yd^2). USGS found that the highest observed concentrations of ammonia occur at river flows of less than 5,000 cfs during the late summer, fall, and winter months. Flows above 5,000 cfs dilute ammonia concentrations to levels below those of toxicological concern.

Toxicity tests performed as part of the USGS risk assessment indicated that Colorado pikeminnow, razorback sucker, and fathead minnow had a 28-day lowest observed effect concentration (LOEC) value for mortality ranging from 2.19 to 4.35 mg/L total ammonia (pH = 8.25 and temperature = 25 °C). USGS estimated effects on individuals at concentrations as low as 0.17 mg/L un-ionized ammonia. Toxicity tests also indicate there were no differences in toxicity across pH within a given temperature. They found that Colorado pikeminnow were more sensitive to ammonia at lower temperatures (8 °C) than at an average condition (18 °C). On-site toxicity tests demonstrated that site waters were directly toxic to both the endangered Colorado pikeminnow and the fathead minnow.

USGS also conducted surveys above and below Moab Wash to determine if ammonia or other ground water constituents were influencing the invertebrate food resources. Results indicate that the benthic invertebrate community distribution was not affected by ammonia concentrations.

Comparisons of laboratory and field results indicate that ammonia is the primary contaminant of concern due to high exposure and rapid onset of toxicity. Metals and radiochemicals, although sometimes elevated above benchmarks, did not contribute to toxicity. Continued monitoring of ammonia levels during ground water remediation would be necessary to ensure protection of aquatic biota. Ammonia would be assessed further during proposed active ground water remediation.

Figure A2–3. Sampling Results for Ammonia in Surface Water at the Moab Site
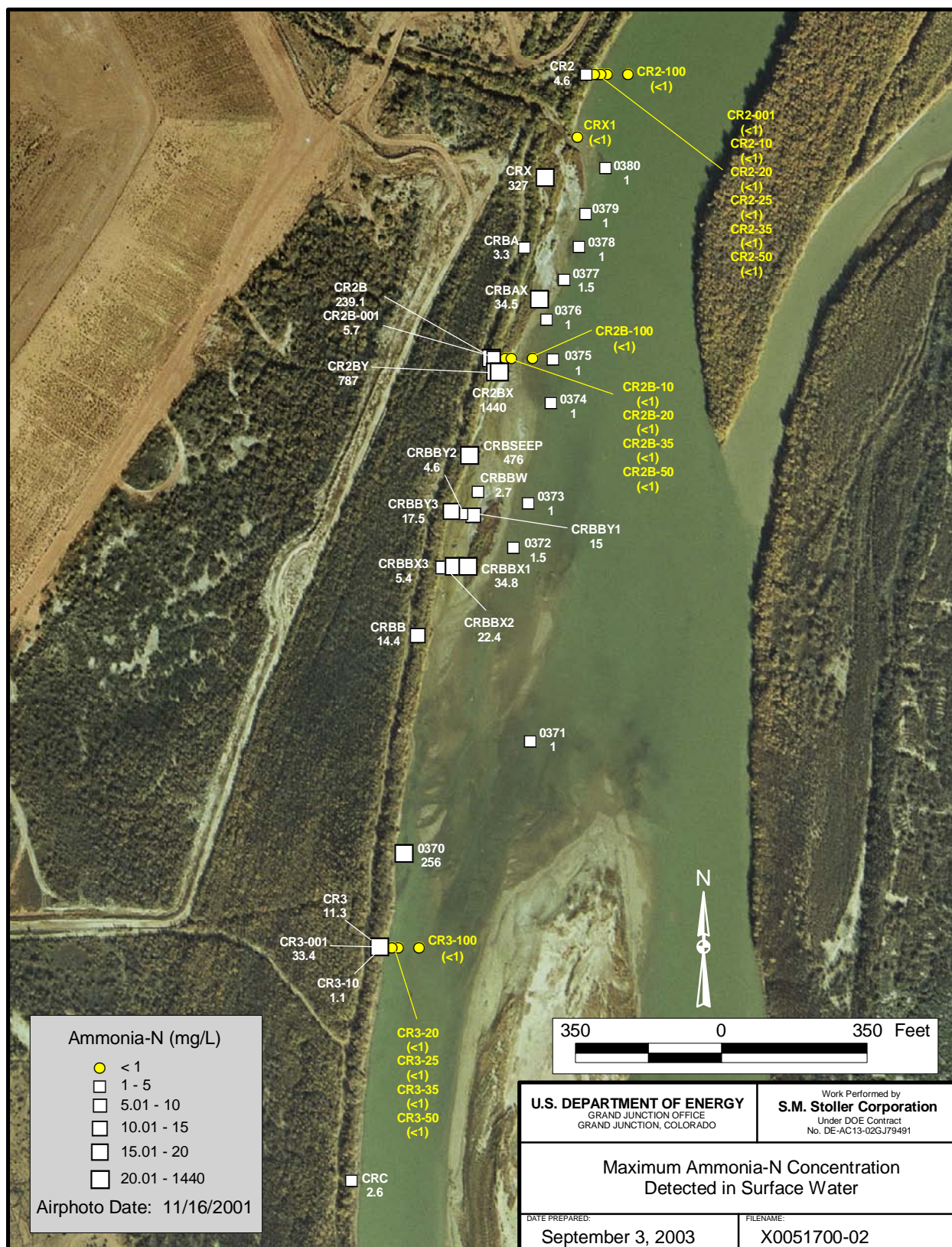
Barium. Barium is a silvery-white metal that reacts readily with water to form barium hydroxide ($Ba(OH)_2$) and hydrogen gas. The toxicity of barium to fish is not well documented. The toxicity of barium to mammals ranges from muscular paralysis to cardiovascular effects (EPA 2003). Barium is concentrated in the bone, the choroids of the eye, and the lung of mammals (Hope et al. 1996). Background ground water concentrations near Moab range from 0.0222 to 0.121 mg/L. The mean concentration in the fresh Qal facies is 0.028 mg/L, and the mean concentration in the brine Qal facies is 0.076 mg/L (DOE 2003 and Chapter 3.0 of the EIS). There are no federal or state surface water quality criteria for protection of aquatic species for barium. Maximum background ground water concentrations exceed Tier II chronic criteria. Background surface water concentrations range from 0.051 to 0.14 mg/L. All 13 of the background surface water samples exceed Tier II chronic criteria, and one of the samples exceeds Tier II acute criteria. Four of the 186 surface water samples taken near Moab had barium concentrations that were above background and Tier II acute and chronic criteria. Of these four samples, three were taken from the river and one was taken from a seep. One of the river samples (0.182 mg/L) was taken from a 4-ft by 5-ft pool with no flow. The remaining two samples were found near backwater areas during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of barium that would cause a chronic impact are unlikely due to changes in river flow. Also, the concentrations in these two samples (0.152 mg/L and 0.155 mg/L) were not substantially different from maximum background concentrations (0.14 mg/L). Based on the background ground water and surface water concentrations, an acute or chronic effect resulting from barium only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to barium are small, and further assessment is not warranted.

Boron. Boron is widely distributed in the environment and has been found to be essential for the early embryonic development of frogs and may be required for reproduction in some fish (Loewengart 2001). At high doses, it has been reported to be teratogenic in mammals; at lower doses, it has been shown to be an essential micronutrient in vascular plants and lower vertebrate animals (Loewengart 2001). Surface water concentrations in the United States, Canada, and the United Kingdom have mean concentrations from 0.10 to 0.16 mg/L boron (Loewengart 2001). In the western United States, 5 to 15 mg/L may be found in surface waters because of weathering of boron-rich formations and deposits (Loewengart 2001). Background ground water concentrations near the Moab site range from 0.106 to 1.33 mg/L (DOE 2003). Background surface water samples near the Moab site have boron concentrations that range from 0.0801 to 0.123 mg/L. One of the 10 background surface water samples (0.123 mg/L) is above Tier II acute and chronic criteria. Nine of the 76 surface water samples near the Moab site were above background and Tier II acute and chronic criteria. The highest concentration of boron (1.74 mg/L) was collected in January in a seep downstream of the tailings pile. Three of the samples were collected near backwater areas during the time when juvenile endangered fish might be in the region. The five remaining samples were in areas not considered backwater habitat. The conditions necessary for aquatic biota to be exposed to elevated levels of boron that would cause a chronic impact are unlikely due to changes in river flow. Hamilton examined the acute toxicity of boron on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail (Hamilton 1995). He found a mean 96-hour lethal concentration 50 (LC_{50}) of 337 mg/L boron. The most sensitive fish life stage was juvenile fish (0.4 to 2.0 grams) of all species with 96-hour LC_{50}s of greater than 100 mg/L boron. Based on the background ground water and surface water concentrations, as well as species-specific laboratory testing, an acute or chronic effect resulting from boron only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to boron are small, and further assessment is not warranted.

Cadmium. Cadmium is a silvery-white metal that is relatively rare in the environment. It is an essential micronutrient for plants but can be toxic to aquatic organisms at concentrations just slightly higher (EPA 2001c). Toxic effects include pericardial and abdominal edema, reduced growth, and poor yolk utilization in larval and juvenile fish (Rand and Petrocelli 1985). A variety of factors modify the toxicity of cadmium to aquatic organisms. These factors include the species, size, and age of the organism; water hardness; pH; and the other constituents in the water (EPA 2001c). Background ground water concentrations at the Moab site range from less than 0.0001 to 0.014 mg/L. Background surface water concentrations are below detection limits (12 samples collected). Six of the 114 surface water samples collected have cadmium levels above benchmarks. Three of these were above acute NWQC and the State of Utah acute criteria, and six were above the NWQC and State of Utah chronic criteria. Two of the samples above the acute and chronic criteria were collected in the river during July and August. The other sample above acute criteria was collected in a seep in April. The remaining three samples above chronic criteria were collected in the river and in seeps during January and April.

If the NWQC acute criteria for cadmium were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the acute cadmium criteria would increase from 0.002 to 0.006 mg/L cadmium. The State of Utah acute criteria would increase from 0.0039 to 0.013 mg/L cadmium (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.00025 to 0.00055 mg/L cadmium (EPA 2002). The State of Utah chronic criteria would increase from 0.0011 to 0.0024 mg/L cadmium. With these criteria corrected for total hardness, none of the samples collected exceeded the NWQC or State of Utah acute criteria. Five of the samples exceeded the corrected NWQC chronic criteria, and one exceeded the corrected State of Utah chronic criteria. The conditions necessary for aquatic biota to be exposed to elevated levels of cadmium that would cause a chronic impact are unlikely due to changes in river flow.

The mean background ground water concentration measured in the brine Qal facies of the aquifer is 0.004 mg/L cadmium, which is equal to the highest surface water sample concentration. The mean background ground water concentration measured in the fresh Qal facies is 0.0017 mg/L. These ground water concentrations are likely to be contributing to the surface water sample concentrations. Studies have shown that pre-exposure to cadmium leads to an elevation of the acute toxic concentration (Wicklund et al. 1990). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of cadmium from natural levels in the ground water. The natural ground water concentration, small number of samples with concentrations above benchmarks, and the sample locations and dates indicate that impacts to aquatic resources from cadmium are likely to be small. Thus, the potential impacts to aquatic resources from exposure to cadmium are small, and further assessment is not warranted.

Chloride. Chloride is an anion. The effects of chloride are primarily associated with the complexes of chloride and heavy metals, and in high concentrations, as the main contributor to salinity. The background ground water concentration for chloride ranges from 135 to 52,388 mg/L. The mean background concentration in the fresh Qal facies is 1,990 mg/L, and the mean background concentration in the brine Qal facies is 29,200 mg/L. A shallow ground water sample in the Matheson Wetlands Preserve across the river from the site has concentrations of chloride exceeding 29,000 mg/L (DOE 2003). These concentrations occurring naturally in the ground water are well above the acute NWQC. Chloride was detected in all 20 background surface water samples, with concentrations ranging from 25 to 172 mg/L. Fifty-one surface water samples collected near the Moab site had concentrations above background surface water

concentrations. Thirteen of these samples had concentrations above the acute NWQC, and concentrations in 27 are above the chronic NWQC. Fourteen of the samples with concentrations that exceed benchmarks were collected in pools with little or no flow. The sample with the maximum concentration (17,300 mg/L) was collected in January from a seep. This high concentration indicates that ground water near the Moab site and the Matheson Wetlands Preserve may be influencing surface water concentrations. In the Colorado River Basin, the influence of chloride from natural sources is likely (DOE 2003). Studies indicate that aquatic biota acclimate to increased salinity due to high concentrations of chloride or other anions (Buttner et al. 1993). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of chloride from natural levels in the ground water. Impacts to aquatic resources from chloride are likely to be small. Thus, the potential impacts to aquatic resources from exposure to chloride are small, and further assessment is not warranted.

Copper. Copper is a micronutrient and an essential component of numerous metabolic pathways and enzymes (Rand and Petrocelli 1985, Magos and Suzuki 1996). Ingestion of copper in excess of nutritional needs can lead to accumulation in the liver, anorexia, edema, disorientation, and scale protrusion (Rand and Petrocelli 1985, Wedemeyer et al. 1976). A variety of factors modify the toxicity of copper to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Fish, invertebrates, and aquatic plants appear to be equally sensitive to chronic toxicity (EPA 2003). Copper was detected in three of the 13 background surface water samples, with concentrations ranging from 0.0006 to 0.0014 mg/L. Background concentrations in the ground water range from 0.0004 to 0.007 mg/L. Background surface water and ground water concentrations are below all benchmarks. Five of the 182 samples collected for copper had concentrations above acute NWQC and State of Utah acute criteria. Eight had concentrations above chronic NWQC and State of Utah chronic criteria. Three of the samples above the benchmarks were collected in seeps, and the remaining five were collected in the river. The samples were collected near backwater areas during the time when juvenile endangered fish might be in the region.

If the criteria for copper were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute copper criteria would increase from 0.013 to 0.040 mg/L copper (EPA 2002). The State of Utah acute criteria would increase from 0.018 to 0.051 mg/L copper (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.009 to 0.024 mg/L copper (EPA 2002). The State of Utah chronic criteria would increase from 0.012 to 0.030 mg/L copper. With these criteria corrected for total hardness, only one of the samples exceeded the NWQC and State of Utah acute or chronic criteria.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that copper concentrations exceeded the State of Utah water quality criteria at several locations during each sampling event. However, USGS concluded that "concentrations of these constituents [copper and zinc] are transient and do not approach levels demonstrated in the laboratory as acutely toxic to razorback suckers or Colorado pikeminnow" (USGS 2002).

Copper has been found to be the primary toxic component of mixtures of contaminants similar to those found at the Moab site (Buhl and Hamilton 1996). Copper has also been implicated as a potential site-related contaminant in previous discussions and in correspondences with USF&WS (NRC 1999). In addition, process knowledge from the site indicates that copper was likely a contaminant in the pile and waste areas (DOE 2003). Continued monitoring of copper levels

during ground water remediation would be necessary to ensure protection of aquatic biota. Copper would be assessed further during active ground water remediation.

Iron. Iron is a micronutrient and is essential in a variety of biochemical reactions. However, in higher concentrations, iron can be toxic to aquatic biota (Magos and Suzuki 1996). Ingestion of iron in excess of nutritional needs can lead to accumulation in the liver (Magos and Suzuki 1996). A variety of factors modify the toxicity of iron to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Background surface water concentrations range from 0.0075 to 4.17 mg/L (nine samples collected). Background concentrations in the ground water range from 0.0008 to 22.3 mg/L. The mean concentration in the fresh Qal facies is 0.009 mg/L and from the brine Qal facies is 9.14 mg/L. The mean concentration in the brine Qal facies is above the chronic NWQC and the acute and chronic State of Utah water quality criteria. Fourteen of the 119 surface water samples collected had copper concentrations that were above the chronic NWQC and the acute and chronic State of Utah water quality criteria. These samples were taken in August 2002 during a sampling event where paired samples (one filtered and one unfiltered) were collected. Results indicate that the iron is bound to a particulate that can be removed with a filter. Iron was the only analyte from that sampling event in which filtering the sample before analysis lowered the concentration by more than an order of magnitude. In the state of Utah, filtered samples are the only samples that should be used for comparison to benchmarks (UAC 2003). The one filtered sample above benchmarks was collected from the river in August. Though it was collected in the river during a time when juvenile endangered fish might be in the region, it was not in an area with backwater habitat. Conditions necessary for fish to be exposed to chronic conditions are unlikely. Natural ground water concentrations and the small number of samples with concentrations above the benchmarks indicate that impacts to fish resulting from iron contamination related to the Moab site are unlikely. Thus, the potential impacts to aquatic resources from exposure to iron are small, and further assessment is not warranted.

Lithium. There is very little in the literature on the toxicity of lithium to aquatic organisms. A study by Hamilton (1995) indicated that lithium is as toxic to fish as selenite and uranium, especially at early life stages. Background ground water concentrations range from 0.0278 to 1 mg/L. The mean concentration in samples from the fresh Qal facies is 0.0873 mg/L, and the mean concentration in samples from the brine Qal facies is 0.143 mg/L, which is above the Tier II chronic benchmark. Three background surface water samples have been collected; lithium concentrations in two were below detection limit and the other had a concentration of 0.057 mg/L. One of the 18 surface water samples collected near the Moab site had a lithium concentration above the Tier II acute benchmark, and 14 samples had concentrations above the Tier II chronic benchmark. All of these samples were collected in the river during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of lithium that would cause a chronic impact are unlikely due to changes in river flow.

Hamilton (1995) examined the acute toxicity of lithium on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail. He found a mean 96-hour LC_{50} of 42 mg/L lithium. The most sensitive fish life stage was the swim-up fry (10 to 31 days old) of all species, with 96-hour LC_{50}s ranging from 17 to 25 mg/L lithium. Background ground water concentrations, as well as species-specific laboratory testing, indicate that impacts to fish resulting from lithium contamination related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to lithium are small, and further assessment is not warranted.

Manganese. Manganese is a metallic element that occurs naturally in rock and soils/sediments weathered from rock. It is most abundant in areas of metamorphic and sedimentary rock. Dissolution from rock and soils/sediments into ground water and surface water has resulted in the presence of varying levels of manganese in natural waters (Reimer 1999). It is an essential trace element for microorganisms, plants, and animals and is therefore present in almost all organisms (Magos and Suzuki 1996). Manganese is a constituent in a variety of enzymes and is an essential part of enzyme systems that metabolize proteins and energy in all animals (Reimer 1999, Magos and Suzuki 1996). A variety of factors modify the toxicity of manganese to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Toxic effects include anemia, reduced growth, reduction in reproductive potential in fish, and anemia (Srivastava and Agrawal 1983, Stubblefield et al. 1997, Reimer 1999).

Background ground water concentrations range from 0.0001 to 38.5 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0057 mg/L, and the mean concentration in the brine Qal facies is 11.7 mg/L, which is above the Tier II acute benchmark. Eight of the 18 background surface water samples had concentrations above detection, ranging from 0.003 to 0.076 mg/L. Ten of the 260 surface water samples collected had concentrations above the Tier II acute benchmark and the lowest chronic benchmark. Twenty-six of the samples had concentrations above the Tier II chronic benchmark. Thirteen of the samples with concentrations above the benchmarks were collected in pools with little or no flow. The two samples with the highest concentration of manganese were collected from a 4-ft by 5-ft pool with no flow. The ground water concentrations are likely to be contributing to the surface water sample concentrations.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that manganese concentrations exceeded the State of Utah water quality criteria at several locations during each sampling event. However, the concentrations varied spatially with no obvious relationship to the location of the tailings pile (USGS 2002).

Studies have shown that pre-exposure of fish to manganese leads to an elevation of the acute toxic concentration (Stubblefield et al. 1997, Reimer 1999). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of manganese from natural levels in the ground water.

At least half of the manganese samples were collected in the river during the time when juvenile endangered fish might be in the region. In addition, manganese has been implicated as a potential site-related contaminant in previous discussions and correspondences with USF&WS (NRC 1999). Manganese is known to be part of process knowledge and is likely in high concentrations in the waste and tailings pile (DOE 2003). Continued monitoring of manganese levels during ground water remediation would be necessary to ensure protection of aquatic biota. Manganese would be assessed further during active ground water remediation.

Mercury. Mercury is a dense silver-white metal that is liquid at room temperature (Hoffman et al. 1995). The environmental effects of mercury vary with its form, dose, pathway of exposure, and life stage of the affected organism (EPA 2003). Mercury concentrations in all background ground water, background surface water, and surface water samples near the Moab site were below the detection limit. DOE reviewed existing data for mercury in preparation for additional sampling during July 2002. Mercury was detected in 3 of 30 ground water samples collected in

previous monitoring rounds. Only one ground water sample had a concentration (0.003 mg/L) that exceeded the maximum concentration limit of 0.002 mg/L. Review of historical process data and experience at other Uranium Mill Tailings Radiation Control Act (UMTRCA) sites indicate that mercury is not used in the milling process (Stoller 2002). On the basis of process knowledge and the low frequency of detection in ground water, it is unlikely that mercury is a site-related contaminant. The potential impacts to aquatic resources from exposure to mercury are small, and further assessment is not warranted.

Molybdenum. Molybdenum is a cofactor to many enzymes essential to aquatic organisms (Magos and Suzuki 1996; Reid 2002). It is generally considered nontoxic to aquatic organisms. In aquatic systems, it readily forms organometallic complexes (Reid 2002). Toxicity estimates of molybdenum to freshwater fish range from 70 to greater than 3,000 mg/L, depending on the species, size of fish, and test conditions (Reid 2002). Acute sublethal effects include increased ventilation, fused gill lamellae, and hemorrhaging of the gut and pyloric caeca (Reid 2002). The background ground water concentration in the fresh Qal facies ranges from 0.0018 to 0.01 mg/L (mean concentration = 0.0037 mg/L). The ground water concentration in the brine Qal facies was below detection limits. Seventeen of the 18 background surface water samples had concentrations above detection limits, ranging from 0.0028 to 0.007 mg/L. Ten of the 290 surface water samples collected had concentrations above the chronic Tier II benchmark. Three of these samples were collected from seeps, and seven were collected from the river. Two of the samples collected from the river were taken from a 4-ft by 5-ft pool with no flow. The river samples were all collected during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of molybdenum (e.g., to cause a chronic impact) are unlikely due to changes in river flow. The low toxicity of molybdenum as well as the surface water sample locations indicate that impacts to fish resulting from molybdenum contamination are not likely. Thus, the potential impacts to aquatic resources from exposure to molybdenum are small, and further assessment is not warranted.

Nickel. Pure nickel is a hard, silvery-white metal and is abundant in the environment. Nickel combined with other elements occurs naturally in the earth's crust, primarily combined with oxygen (oxides) or sulfur (sulfides), and is found in all soils (EBI 2003). Toxic effects in aquatic systems include tissue damage, genotoxicity, and growth reduction (EPA 2003). A variety of factors modify the toxicity of nickel to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Background ground water concentrations range from 0.0006 to 0.0647 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0022 mg/L, and the mean concentration in the brine Qal facies is 0.0327 mg/L. The background surface water concentration ranges from 0.003 to 0.076 mg/L (10 samples collected). Ground water and surface water concentrations are below all benchmarks. One of the 56 surface water samples collected had a concentration above the chronic NWQC, State of Utah chronic criteria, and the lowest chronic benchmark.

If the criteria for nickel were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute nickel criteria would increase from 0.47 to 1.25 mg/L nickel (EPA 2002). The State of Utah acute criteria would increase from 1.40 to 3.79 mg/L nickel (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.052 to 0.139 mg/L nickel (EPA 2002). The State of Utah chronic criteria would increase from 0.16 to 0.420 mg/L nickel. With these criteria

corrected for total hardness, none of the samples had concentrations that exceeded the NWQC and State of Utah acute or chronic criteria for nickel.

The one sample that exceeded the chronic benchmark without a correction for hardness was collected in the river during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of nickel that would cause a chronic impact are unlikely due to changes in river flow. The low number of samples with concentrations that are above benchmarks indicates that impacts to fish resulting from nickel related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to nickel are small, and further assessment is not warranted.

Nitrate. Ammonia, nitrite, and nitrate are interrelated through the process of nitrification. Nitrification is the biological process during which nitrifying bacteria convert toxic ammonia to less harmful nitrate. Nitrate is considered essentially nontoxic to aquatic organisms (Rand and Petrocelli 1985). Toxic effects include disruption of normal osmoregulatory ability (Rand and Petrocelli 1985). Background ground water concentrations range from 1.22 to 15.9 mg/L. The mean ground water concentration in the fresh Qal facies is 7.58 mg/L, and the mean concentration in the brine Qal facies is 0.0346 mg/L. The mean concentration in the fresh Qal facies is above the acute and chronic State of Utah water quality criteria. The background surface water concentration ranges from 1.86 to 5.51 mg/L. Two of the five background surface water samples had concentrations above the acute and chronic State of Utah water quality criteria. Thirty-eight of the 76 surface water samples collected had concentrations above the acute and chronic State of Utah water quality criteria. At least half of these samples were collected in the river during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of nitrate such as to cause a chronic impact are unlikely due to changes in river flow. Background ground water concentrations, background surface water concentrations, and the relatively low toxicity of nitrate indicate that impacts to fish resulting from nitrate related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to nitrate are small, and further assessment is not warranted.

Selenium. Selenium is a metalloid that occurs ubiquitously in nature but is rarely found in concentrations over 100 mg/L in aquatic systems (Cleveland et al. 1993). Selenium is required in the diet of fish at concentrations of 1.0 to 0.5 micrograms per gram (μg/g) dry weight (Lemly 1998). It is necessary for the formation of enzymes involved in normal cellular and organ metabolism (Lemly 1998). At dietary concentrations 7 to 39 times those required, it becomes toxic (Lemly 1998). Toxic effects include reduced growth, reproductive failure, liver damage, and chromosomal aberrations (Cleveland et al. 1993, EPA 2003).

Background ground water concentrations range from 0.0091 to 0.0266 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0164 mg/L, and the mean concentration in the brine Qal facies is 0.00171 mg/L. The mean concentration in the fresh Qal facies is above the chronic NWQC and the chronic State of Utah water quality criteria. The background surface water concentration ranges from 0.0013 to 0.0079 mg/L. Six of the 15 background surface water samples had concentrations above the chronic NWQC and chronic State of Utah water quality criteria. Seven of the 216 surface water samples collected near the Moab site had concentrations above background, the chronic NWQC, and chronic State of Utah water quality criteria. The selenium level in one of these samples exceeded the acute State of Utah water quality criteria.

Four of these seven samples were collected in pools with little or no flow, and two were collected from seeps.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that selenium concentrations range from 0.001 to 0.004 mg/L as total selenium. However, USGS concluded that the data "provides no indication that selenium from the Atlas Mill Tailings Pile is elevated to levels of localized concern" (USGS 2002).

Background ground water and surface water concentrations, the sample locations, and low number of samples with concentrations above benchmarks indicate that impacts to fish resulting from selenium related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to selenium are small, and further assessment is not warranted.

Silver. Silver may biomagnify in some aquatic invertebrates and is highly toxic to aquatic organisms. Elevated levels of silver can cause larval mortality, developmental abnormalities, and reduced larval growth in fish (EPA 2003). Silver concentrations in all background ground water, background surface water, and surface water samples near the Moab site were below the analytical detection limits. One-half the reported detection limit (EPA 2001a, 2001b) was used to assess these samples. A variety of factors modify the toxicity of nickel to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. One sample collected in the surface water near the Moab site could be above the acute NWQC and State of Utah acute criteria. Two samples could be above the chronic Tier II benchmark, and 33 could be above the lowest chronic benchmarks. The mean concentration of silver in the tailings pore water is 0.0009 mg/L (DOE 2003). This value is below all benchmarks except the "lowest chronic" benchmark.

If the criteria for silver were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute silver criteria would increase from 0.0032 to 0.024 mg/L silver (EPA 2002). The State of Utah acute criteria would increase from 0.0041 to 3.79 mg/L silver (UAC 2003). With these criteria corrected for total hardness, none of the samples had concentrations that exceeded the NWQC and State of Utah acute criteria for silver.

The lack of elevated silver in the tailings pore water and the low number of samples with concentrations above benchmarks indicate that impacts to fish resulting from silver related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to silver are small, and further assessment is not warranted.

Strontium. Strontium is a soft, silver-gray metal that is commonly found in soils. It behaves similarly to calcium in living organisms (Peterson et al. 2002). The uptake of strontium through an organism and through the food chain is affected by the presence of calcium in the system (Driver 1994). The concentration of strontium in the bone and muscle of trout was found to be inversely related to calcium concentrations in the water. Because of its chemical similarity to calcium, strontium is deposited in the bones of vertebrates (Driver 1994). Background ground water concentrations at the Moab site range from 2.25 to 65 mg/L. The mean ground water concentration in the fresh Qal facies is 3.79 mg/L, and the mean concentration in the brine Qal facies is 36.8 mg/L. The mean concentration in the fresh Qal facies is above the chronic Tier II benchmark, and mean concentration in the brine Qal facies is above the acute and chronic Tier II benchmarks. The background surface water concentration ranges from 0.965 to

1.63 mg/L. Concentrations in two of the 10 background surface water samples are above the chronic Tier II benchmark. Twenty of the 136 surface water samples collected near the Moab site had concentrations above the maximum background surface water concentration and the chronic Tier II benchmark. Sixteen of these samples were collected from pools with little or no flow. The natural ground water concentrations are likely to be contributing to the surface water sample concentrations. At least half of these samples were collected in the river during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of strontium that would cause a chronic impact are unlikely due to changes in river flow. Elevated natural ground water concentrations, elevated background surface water concentration, and surface water sample locations indicate that impacts to fish resulting from strontium related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to strontium are small, and further assessment is not warranted.

Sulfate. Sulfate is an anion, and the effects of sulfate are primarily associated with the complexes of sulfate and heavy metals. There are no established benchmarks for sulfate. The background ground water concentrations for sulfate range from 180 to 6,000 mg/L. The mean background concentration in the fresh Qal facies is 772 mg/L, and the mean background concentration in the brine Qal facies is 3,520 mg/L. The surface water background concentrations range from 84.1 to 439 mg/L (20 samples). Fifty-three of the 301 surface water samples collected near the Moab site had concentrations above background. Four of the 53 samples with above background concentrations were collected in seeps. Twenty-eight of the 53 samples were collected in pools with little or no flow, and these samples also had elevated levels of other contaminants of potential concern. Sulfate was used extensively in processing the ore at the Moab site and is a common contaminant at other UMTRCA sites (DOE 2003). Continued monitoring of sulfate levels during ground water remediation would be necessary to ensure protection of aquatic biota. Sulfate would be assessed further during active ground water remediation.

Uranium. Uranium is a silver-colored heavy metal that is nearly twice as dense as lead. It is the heaviest naturally occurring element in nature. Uranium can pose a hazard from its chemical toxicity as well as from its radiological toxicity (internal alpha emission) in biota. However, because of its low specific activity, uranium primarily poses a chemical hazard rather than a radiological hazard in biota (Wrenn et al. 1985; Bosshard et al. 1992). The toxicity of uranium to fish varies with water quality, particularly total hardness and alkalinity (Driver 1994). It accumulates in soils and sediments and enters the food chain by adsorption on surfaces of plants and animals and by ingestion of sediments and contaminated food (Driver 1994; Cooley and Klaverkamp 2000; Swanson 1983). Therefore, bottom-feeding fish species have been found to accumulate the highest concentration of uranium, relative to piscivorous fish (Waite et al. 1988; Swanson 1983, 1985).

Information regarding the accumulation and distribution of uranium in freshwater fish is limited. Available data indicate that the primary sites of uranium accumulation are the bones, scales, gonads, gills, gastrointestinal tract, kidney, and liver (Cooley and Klaverkamp 2000; Swanson 1985; Waite et al. 1988; Holdway 1992). Studies by Cooley et al. (2000) and Holdway (1992) suggest that the liver and kidney may be a significant site for uranium toxicity in fish, causing lesions and malformations.

Uranium in samples from 2000 to 2002 ranged from 0.0013 to 5.12 mg/L (Figure A2–4). Background ground water concentrations range from 0.0042 to 0.0269 mg/L uranium. The mean ground water concentration in the fresh Qal facies is 0.0127 mg/L, and the mean concentration in

the brine Qal facies is 0.00768 mg/L. The mean uranium concentrations in the fresh Qal facies and the brine Qal facies are above the Tier II chronic benchmark. The background surface water concentration ranges from 0.0023 to 0.008 mg/L uranium. Eighteen of the 20 background surface water samples had concentrations above the Tier II chronic benchmark. One hundred seventy-four of 331 surface water samples collected near the Moab site had concentrations above the maximum background surface water concentration and the Tier II chronic benchmark. Forty-two surface water samples had concentrations above the Tier II acute benchmark. Sixteen samples had concentrations above the lowest chronic benchmark.

The calculated criteria by Suter and Tsao (1996) were used to evaluate uranium in surface water because there are no federal or State of Utah standards. The values for the Tier II acute and chronic benchmarks appear to be very low and not reproducible when the published data are recalculated using their methodology. They also developed estimated lowest chronic values for fish extrapolated from laboratory studies. The lowest chronic value is considered conservative in comparison to results of studies on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail (Hamilton 1995).

Hamilton (1995) examined the acute toxicity of uranium on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail. He found a mean 96-hour LC_{50} of 46 mg/L of uranium for all species. Results do not indicate a difference in uranium sensitivity between life stages or species.

Continued monitoring of uranium levels during ground water remediation would be necessary to ensure protection of aquatic biota. Uranium would be assessed further during active ground water remediation.

Vanadium. Vanadium is a steel-gray, corrosion-resistant metal that is likely an essential element to living organisms (Barceloux 1999). There is little information about the toxicity of vanadium to aquatic resources. Background ground water concentrations range from 0.00061 to 0.135 mg/L vanadium. The mean ground water concentration in the fresh Qal facies is 0.00534 mg/L, and the mean concentration in the brine Qal facies is 0.0418 mg/L, which is above the Tier II chronic benchmark. The background surface water concentration ranges from 0.00073 to 0.0031 mg/L. Two of the 148 surface water samples collected near the Moab site had concentrations above the Tier II acute and chronic benchmarks. These two samples were collected from seeps in April, when juvenile endangered fish are not likely to be in the region. The conditions necessary for aquatic biota to be exposed to elevated levels of vanadium that would cause a chronic impact are unlikely due to changes in river flow. Thus, the potential impacts to aquatic resources from exposure to vanadium are small, and further assessment is not warranted.

Synergistic Effects. The list of analytes for the Moab site monitoring of surface water from 2000 to 2002 includes chemicals that may act together to cause synergistic impacts to the listed fish. Mixtures of inorganic metals can be hazardous because metals in a mixture may be present at concentrations below their individual toxic thresholds but sufficiently high to interact additively or synergistically with other inorganics and cause a toxic response in aquatic organisms (Hamilton 1995). Numerous studies have documented additive effects on aquatic organisms,
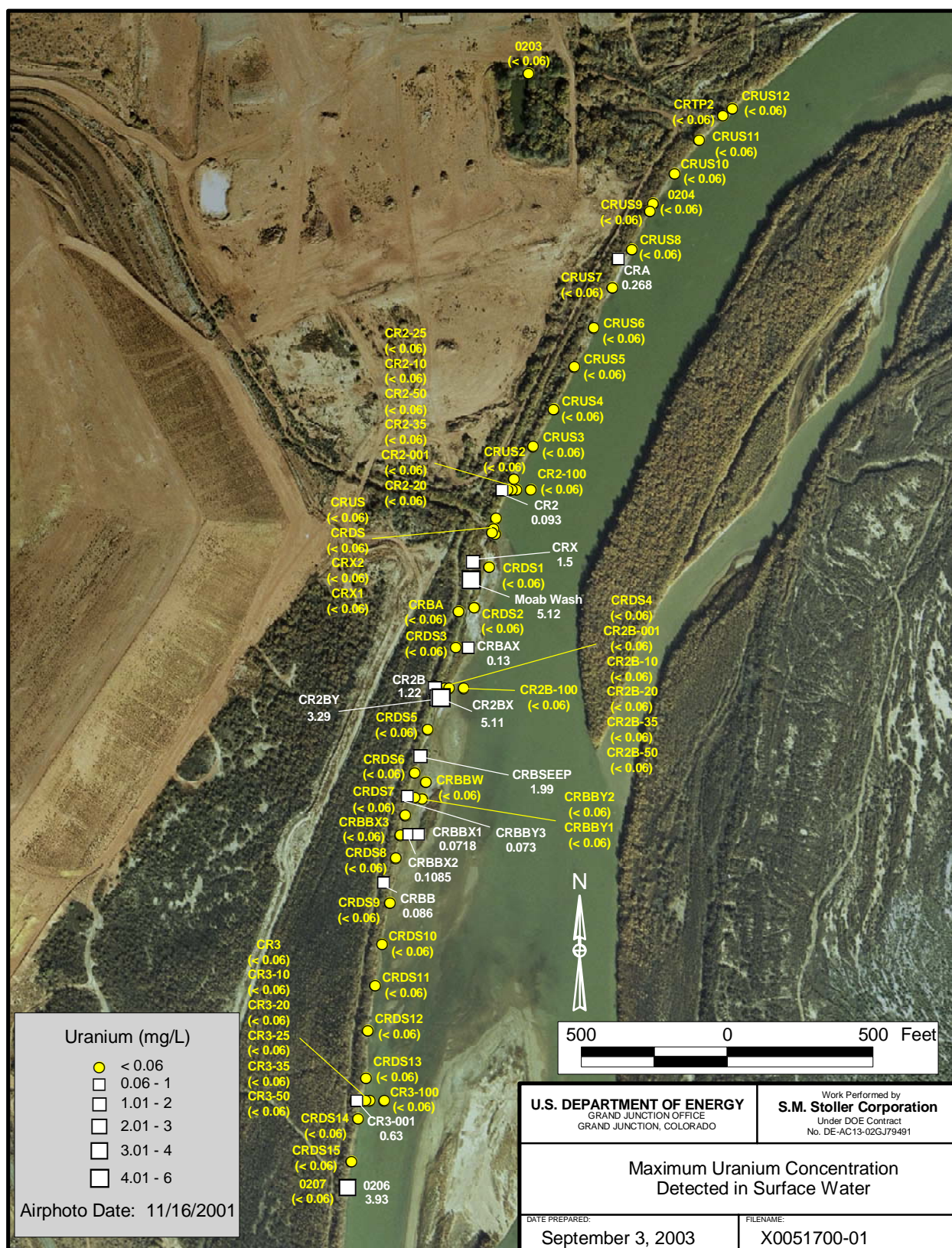
Figure A2–4. Sampling Results for Uranium in Surface Water at the Moab Site

including the Colorado pikeminnow, razorback sucker, and bonytail. Hamilton (1995) found that waterborne concentrations of boron, selenium, and zinc each cause an adverse effect in young Colorado pikeminnows, razorback suckers, and bonytails. In addition, the mixture of these metals with vanadium and uranium increased the toxicity to the fish, yet by themselves, vanadium and uranium were not hazardous. Buhl and Hamilton (1996) considered effects from waterborne mixtures of arsenate, boron, copper, molybdenum, selenate, selenite, uranium, vanadium, and zinc to early life stages of Colorado pikeminnow, razorback sucker, and bonytail. Results indicate that chronic exposure to the mixtures showed a synergistic effect that was species- and life-stage specific. Hamilton et al. (2000) found that mixtures of copper, selenium, and zinc have toxic effects on razorback suckers and bonytails. The results of the USGS site-specific study with the Colorado pikeminnow and the razorback sucker indicate that ammonia toxicity was not affected when ammonia was mixed with other contaminants found in the Colorado River (USGS 2002). Potential impacts to aquatic resources from synergistic effects of ammonia with other contaminants are not likely. Synergistic effects between other metals are possible but are difficult to quantify.

Chemical Impacts to Aquatic Biota. Based on the evaluation of contaminants of potential concern, the chemical contaminants that would require future assessment and continued monitoring during proposed active ground water remediation activities for the Moab site are ammonia, copper, manganese, sulfate, and uranium. The proposed ground water extraction near the Colorado River and the use of freshwater injection would decrease the maximum concentrations of these contaminants of concern in the nearshore environment to levels below acute and chronic benchmarks. Potential synergistic effects between contaminants would be reduced through ground water remediation. For these contaminants of concern, for both acute and chronic benchmarks, continued monitoring during ground water remediation activities would be necessary to ensure acceptable conditions for protection of aquatic biota.

Radiological Impacts to Aquatic Biota. The primary route by which radioactive contamination enters the aquatic environment at the Moab site is through ground water. The routes of exposure for the radioactive contaminants are the same as those for chemical impacts. The contributors to radiological dose to the aquatic organisms at the Moab site that have been monitored include lead-210, polonium-210, radium-226, radium-228, radon-222, thorium-230, uranium-234, and uranium-238, and the general indicator of radionuclides, gross alpha and gross beta.

The RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) was used to screen the dose rate to aquatic organisms based on the maximum observed concentrations of uranium-238, uranium-234, and radium-226 (DOE 2002). These isotopes represent the highest values analyzed for radionuclides in 2000 to 2002. The protocol for screening assessment includes multiple tiers. The first-tier screening assessment using the maximum observed concentrations had a sum of fractions that equaled 3.16, which exceeded the DOE guidance level of 1.0 for aquatic biota. A second-tier analysis based on mean concentrations of these three radionuclides of those values above detection resulted in a sum of fractions value of 0.29. The results of the second-tier analysis indicate that dose rates are below the guidance level associated with the 1.0-rad-per-day criterion adopted by DOE for screening dose rates to aquatic organisms.

The results of the RESRAD assessment indicate that the actual dose rates to aquatic organisms are below a population effect level. There are no guidelines for radiological effects to individuals, which is important in evaluating impacts to threatened and endangered species. The studies that were completed for the 1.0-rad-per-day criterion were based on exposures to

organisms for 1 year, and then normalized to a dose rate based on a day. One can interpret these results to mean that a dose rate of 1.0 rad per day, if sustained for a year, would have an effect on some individuals but not on the population as a whole. Based on monitoring results from 2000 to 2002 and on the life styles of the endangered fish around the Moab site, radiological effects currently are not expected to adversely affect the aquatic environment.

Ground water extraction near the Colorado River and the use of freshwater injection would further decrease the maximum concentrations of radionuclides along the shoreline of the Moab site. These activities would be necessary to reduce impacts from chemical contaminants. They would also reduce the potential for radiological effects to individuals, which is important to endangered species as well as populations.

Long-term impacts would depend on the cover design and cover effectiveness to maintain radioactive contaminants below their current concentrations. As long as the dose rate to aquatic biota from radioactive contaminants remained below that measured from 2000 to 2002, there would be no impacts to individuals or populations.

Gross Alpha. Gross alpha is a screening assay to measure all the alpha activity present in a sample, regardless of the specific radionuclide source. Such measurements are used as a method to screen samples for relative levels of radioactivity (INEEL 2001). The alpha-emitting radionuclides at the Moab site are uranium-238, radon-222, radium-226, and polonium-210. The State of Utah water quality standard for gross alpha is 15 pCi/L (UAC 2003). A total of 93 surface water samples were analyzed for gross alpha from 2000 to 2002; seven samples were collected at background locations; concentrations ranged from <7.3 to 13.82 pCi/L. Gross alpha activity in surface water samples near the Moab site ranged from 8 to 665 pCi/L; the maximum activity was detected in a sample from location CR2B (Figure A2–4). Samples with gross alpha activity that exceeded the State of Utah water quality standard (37 samples) were located in regions where uranium concentrations were highest. Overall, radiochemicals do not appear to be a concern to aquatic biota in the Colorado River adjacent to the site. USGS concluded that there would be "no significant biological impacts to fish populations caused by radionuclide concentrations sampled in the Colorado River and sediments." They found that "radiochemical concentrations are elevated in ground water below the Moab pile; however, these waters do not result in a high radiation exposure to fish" (USGS 2002). Continued monitoring of uranium levels would be appropriate for addressing impacts to the aquatic biota and directly evaluating proposed activities to remediate the site.

A2–2.0 Screening for Terrestrial Biota

Chemical Impacts to Wildlife. Samples of nonradiological constituents in surface water were collected by SMI and USGS between 2000 and 2002. The rationale for screening the original 28 contaminants to select two contaminants of potential concern for wildlife (mercury and selenium) was the same as the process described above for aquatic biota (involving comparison of maximum contaminant concentrations in surface water with detection limits, background concentrations, and toxicological benchmarks), except that different toxicological benchmarks were used.

Wildlife could be exposed to contaminants through ingestion of prey and water and through incidental soil ingestion, inhalation of airborne contaminants, and dermal uptake. The primary

pathway for wildlife exposure to contaminants would likely be through ingestion of prey in the riparian zone and of prey and water in the surface waters of the nearshore environment.

The selection of contaminants of potential concern could not be based on ingestion of prey in the riparian zone because contaminant data for local riparian biota were not available for comparison with tissue concentration benchmarks (milligrams per kilogram [mg/kg]) based on ingestion. Consequently, in addition to the process described above for aquatic biota, the selection of contaminants of potential concern was based on the potential for chronic effects via ingestion of prey and water within the surface waters of the nearshore environment. This was evaluated by comparing contaminant concentrations in surface water with mammalian and avian drinking water benchmarks (mg/L) that would result in NOAELs (mg/kg/day) and LOAELs (mg/kg/day), and with piscivorous mammalian and avian food/water benchmarks (mg/L) that would result in NOAELs (mg/kg/day) and LOAELs (mg/kg/day). NOAEL benchmarks are values believed to be nonhazardous. LOAEL benchmarks are threshold values for which chronic adverse effects are likely to become evident.

Sample et al. (1996) provides drinking water benchmarks for 9 mammalian wildlife species (cottontail rabbit, little brown bat, meadow vole, mink, red fox, river otter, short-tailed shrew, white-footed mouse, and whitetail deer) and 11 avian wildlife species (American robin, American woodcock, barn owl, barred owl, belted kingfisher, Cooper's hawk, great blue heron, osprey, red-tailed hawk, rough-winged swallow, and wild turkey). The lowest mammal and bird NOAEL- and LOAEL-based drinking water benchmarks (Tables A2–4 and A2–5, respectively) were used to select contaminants of potential concern. In addition, Sample et al. (1996) provides food/water benchmarks for two piscivorous mammals (river otter and mink) and three piscivorous birds (belted kingfisher, great blue heron, and osprey). The lowest of the piscivorous mammal and the lowest of the piscivorous bird NOAEL- and LOAEL-based food/water benchmarks were also used to select contaminants of potential concern (Tables A2–4 and A2–5, respectively).

Drinking water and/or food/water toxicity benchmarks that were exceeded by maximum contaminant concentrations are identified by an asterisk in tables A2-4 and A2-5 (i.e., aluminum, cadmium, mercury, molybdenum, and selenium). However, for some constituents (i.e., iron, molybdenum, and silver), there were no existing drinking water or food/water toxicity benchmarks (Sample et al. (1996). For these constituents, these benchmarks were derived using the methodology presented in Sample et al. (1996) and supporting data from the toxicological literature, where such was available. However, for some of these constituents (i.e., ammonia, chloride, nitrate, and sulfate), there was insufficient data from the toxicological literature to support derivation of the benchmarks. In such cases, these constituents were evaluated on the basis of other rationale, such as exceedance of livestock drinking water standards. These 11 constituents are considered preliminary contaminants of potential concern and are identified by an asterisk in Table A2–6. The evaluation of these preliminary contaminants of concern are discussed in the following paragraphs in terms of their exclusion or retention as final contaminants of concern (i.e., mercury and selenium).

Table A2–4. Surface Water Concentrations of Contaminants With Minimum Mammal NOAEL- and LOAEL-Based Drinking Water Benchmarks and Piscivorous Mammal NOAEL- and LOAEL-Based Food/Water Benchmarks.

(All mammal NOAEL- and LOAEL-based drinking water benchmarks were for the white-tailed deer, except for mercury, which was for the river otter, with multiple benchmarks separated by commas. Piscivorous mammal NOAEL- and LOAEL-based food/water benchmarks are provided, in order, for river otter and mink, with multiple benchmark values for each species separated by commas and enclosed in parentheses. Benchmark values exceeded by maximum concentrations are denoted with an asterisk and are of potential concern and are therefore discussed in the text.)

Constituent	Min. (mg/L or pCi/L)	Mean (mg/L or pCi/L)	Max. (mg/L or pCi/L)	Background range or maximum (mg/L or pCi/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)
Aluminum	0.005	0.02164	0.348[a]	0.008–0.14	4.474	44.738	0.018*, 0.025*	0.183*, 0.253*
Ammonia[b]	0.05		1,440	0.05–0.134	N/A[c]	N/A	N/A	N/A
Antimony			0.0005[d]	0.0005[d]	0.290	2.898	0.161, 0.220	1.607, 2.204
Arsenic			0.002[e]	<0.0006–0.002	0.292	2.921	0.016, 0.022	0.156, 0.216
Barium	0.002		0.211	0.051–0.14	23.1	84.8	N/A	N/A
Beryllium			0.00005[d]	0.00005[d]	N/A	N/A	N/A	N/A
Bismuth			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Boron	0.064		1.74	<0.0801–0.123	120	401	N/A	N/A
Cadmium	<0.0001	0.00095	0.004	<0.00005[d]	4.132, 68.135	41.323	3.162E-04*, 4.367E-04*	3.162E-03*, 4.367E-03
Chloride	22		17,300	25–172	N/A	N/A	N/A	N/A
Chromium			0.0005[d]	<0.0005–<0.0013	14.05 (Cr+6), 11725 (Cr+3)	56.29 (Cr+6)	3.593 (Cr+6), 4.947 (Cr+6)	14.394 (Cr+6), 19.817 (Cr+6)
Copper	<0.00049		0.051[a]	<0.0006–<0.0014	65.2	85.8	0.213, 0.294	0.280, 0.387
Iron[f]	<0.003	0.098	3.08	0.0075–0.0178	N/A	N/A	N/A	N/A
Lead			0.0005[d]	0.00005[d]	34.27	342.72	0.711, 0.982	7.115, 9.823
Lithium	0.0552		0.31[e]	0.057[e]	40.3	80.5	N/A	N/A
Manganese	0.0005		12	<0.003–0.076	377	1217	N/A	N/A
Mercury	<0.0002	N/A	0.002[a]	0.00005[d]	0.111	0.186	1.576E-06*, 3.924E-06*	2.626E-06*, 6.540E-06*
Molybdenum	<0.001	0.05195	1.91	<0.0028–0.007	0.6*	6.03	N/A	N/A
Nickel	<0.0006		0.052	<.0006–0.002	171.36	342.72	1.524-2.104	3.048-4.209
Nitrate	0.829		21.7	1.86–5.51	2719	6061	N/A	N/A
Selenium	<0.0005	0.00446	0.026	0.0013–0.0079	0.857	1.414	2.363E-04*, 4.318E-04*	3.899E-04*, 7.12E-04*
Silver	<0.005		0.0025[d]	0.00005[d]	N/A	N/A	N/A	N/A
Strontium	0.005		10.2	0.965–1.63	1127	N/A	N/A	N/A
Sulfate	72		14400	84.1–439	N/A	N/A	N/A	N/A
Thallium			0.0005[d]	0.0005[d]	0.032	0.320	0.001	0.009, 0.012
Uranium	0.0013		5.12	0.0023–0.008	6.995	13.996	N/A	N/A
Vanadium	0.0003		0.249	0.00073–0.0031	0.835	8.352	N/A	N/A
Zinc			0.023	<0.0017–0.006	685.4	1370.9	0.673, 0.929	1.346, 1.858

[a]Concentration is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]N/A = not available.
[d]All concentrations were below detection; maximum value based on one-half of detection limit.
[e]Values in data set represent multiple detection limits. This is the highest value in the data that was above its respective detection limit.
[f]Values reported for this constituent are based only on unfiltered samples in order to conform to UAC (2003).
*Benchmark exceeded by maximum contaminant concentration.

Table A2–5. Surface Water Concentrations of Contaminants with Minimum Bird NOAEL- and LOAEL-Based Drinking Water Benchmarks and Piscivorous Bird NOAEL- and LOAEL-Based Food/Water Benchmarks.

(All bird NOAEL- and LOAEL-based drinking water benchmarks were for the rough-winged swallow, with multiple benchmarks separated by commas. Piscivorous bird NOAEL- and LOAEL-based food/water benchmarks are provided, in order, for belted kingfisher, osprey, and great blue heron, with multiple benchmarks values for each species separated by commas and enclosed in parentheses. Benchmark values exceeded by maximum concentrations are denoted with an asterisk and are of potential concern and are therefore discussed in the text.)

Constituent	Min. (mg/L or pCi/L)	Mean (mg/L or pCi/L)	Max. (mg/L or pCi/L)	Background mg/L or pCi/L	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)
Aluminum	0.005	0.02164	0.348[a]	0.008–0.14	471.4	191.2	0.936, 2.372, 2.699	0.380, 0.962, 1.095
Ammonia[b]	0.05		1440	0.05–0.134	N/A[c]	N/A	N/A	N/A
Antimony			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Arsenic			0.002[e]	<0.0006–0.002	10.6, 22.1	31.7, 55.2	(0.282, 0.589), (0.713, 1.489), (0.811, 1.695)	(0.846, 1.472), (2.138, 3.720), (2.434, 4.235)
Barium	0.002		0.211	0.051–0.14	89.4	179.2	N/A	N/A
Beryllium			0.00005[d]	0.00005[d]	N/A	N/A	N/A	N/A
Bismuth			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Boron	0.064		1.74	<0.0801–0.123	124	430	N/A	N/A
Cadmium	<0.0001	0.00095	0.004	<0.00005[d]	6.23	85.95	2.307E-04*, 0.001*, 0.001*	3.183E-03*, 8.0E-03, 9.0E-03
Chloride	22		17300	25–172	N/A	N/A	N/A	N/A
Chromium			0.0005[d]	<0.0005–<0.0013	4.30 (Cr+3)	21.49 (Cr+3)	N/A	N/A
Copper	<0.00049		0.051[a]	<0.0006–<0.0014	202	265.1	0.32, 0.81, 0.921	0.420, 1.063, 1.210
Iron[f]	<0.003	0.098	3.08	0.0075–0.0178	N/A	N/A	N/A	N/A
Lead			0.0005[d]	0.00005[d]	4.86, 16.54	48.56	0.049, 0.125, 0.142	0.493, 1.248, 1.421
Lithium	0.0552		0.31[e]	0.057[e]	N/A	N/A	N/A	N/A
Manganese	0.0005		12	<0.003–0.076	4284	N/A	N/A	N/A
Mercury	<0.0002	N/A	0.002[a]	0.00005[d]	0.028, 1.93	0.275, 3.87	4.527E-07*, 1.147E-06*, 1.305E-06*	4.527E-06*, 1.147E-05*, 1.305E-05*
Molybdenum	<0.001	0.05195	1.91	<0.0028–0.007	15.04	151.69	N/A	N/A
Nickel	<0.0006		0.052	<.0006–0.002	332.61	459.81	1.438, 3.642, 4.145	1.988, 5.035, 5.731
Nitrate	0.829		21.7	1.86–5.51	N/A	N/A	N/A	N/A
Selenium	<0.0005	0.00446	0.026	0.0013–0.0079	1.719, 2.149	3.438, 4.297	3.795E-04*, 9.614E-04*, 1.094E-03*	7.589E-04*, 1.923E-03*, 2.188E-03*
Silver	<0.005		0.0025[d]	0.00005[d]	N/A	N/A	N/A	N/A
Strontium	0.005		10.2	0.965–1.63	N/A	N/A	N/A	N/A
Sulfate	72		14400	84.1–439	N/A	N/A	N/A	N/A
Thallium			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Uranium	0.0013		5.12	0.0023–0.008	68.8	N/A	N/A	N/A
Vanadium	0.0003		0.249	0.00073–0.0031	48.989	N/A	N/A	N/A
Zinc			0.023	<0.0017–0.006	62.3	562.9	0.030, 0.075, 0.085	0.268, 0.678, 0.771

[a]Concentration is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]N/A = not available.
[d]All concentrations were below detection; maximum value based on one-half of detection limit.
[e]Values in data set represent multiple detection limits. This is the highest value in the data that was above its respective detection limit.
[f]Values reported for this constituent are based only on unfiltered samples in order to conform to UAC (2003).
*Benchmark exceeded by maximum contaminant concentration.

Table A2–6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Aluminum	0.348[a]	0	0	0	0	0	0	17*	2*	Maximum concentration is above background and piscivorous mammal NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Ammonia	1440	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Antimony	0.0005[b]	N/A	N/A	N/A	N/A	0	0	0	0	Maximum concentration is equal to background and both are below detection limits. Half detection limit is below all benchmarks. Not retained as preliminary COPC.
Arsenic	0.002[c]	0	0	0	0	0	0	0	0	Maximum concentration is equal to highest background concentration. Maximum and background concentrations are both below all benchmarks. Not retained as preliminary COPC.
Barium	0.211	0	0	N/A	N/A	0	0	N/A	N/A	Maximum concentration is above background concentration. Maximum and background concentrations are both below all benchmarks. Not retained as preliminary COPC.
Beryllium	0.00005[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measured concentrations and background concentrations are below detection limits. Measured concentration detection limit is equal to background detection limit. (No wildlife benchmarks available.) Not retained as preliminary COPC.

Table A2–6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks (continued)

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Bismuth	0.0005[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measured concentrations and background concentrations are below detection limits. Measured concentration detection limit is equal to background detection limit. (No wildlife benchmarks available.) Not retained as preliminary COPC.
Boron	1.74	0	0	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration and background below all benchmarks. Not retained as preliminary COPC.
Cadmium	0.004	0	0	8*	1*	0	0	8*	1*	Maximum concentration above background and above picscivorous bird and picscivorous mammal NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Chloride	17300	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Chromium	0.0005[b]	0	0	N/A	N/A	0	0	0	0	Maximum concentration equal to low background. Maximum concentration and background below all Cr+6 and Cr+3 benchmarks. Not retained as preliminary COPC.
Copper	0.051[a]	0	0	0	0	0	0	0	0	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Iron	3.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Lead	0.0005[b]	0	0	0	0	0	0	0	0	Maximum concentration is above background and both are below detection limits. Half detection limit of maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Lithium	0.31[c]	0	0	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. Maximum concentration is below detection limits. Half detection limit is below all benchmarks. Not retained as preliminary COPC.
Manganese	12	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Mercury	0.002[a]	0	0	85*	85*	0	0	85*	85*	Maximum concentration is above background. Maximum concentration is above piscivorous mammal and piscivorous bird NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Molybdenum	1.91	0	0	N/A	N/A	8*	0	N/A	N/A	Maximum concentration is above background and above mammal NOAEL-based drinking water benchmark. No piscivorous wildlife benchmarks available. Retained as preliminary COPC.*

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Nickel	0.052	0	0	0	0	0	0	0	0	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Nitrate	21.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Selenium	0.026	0	0	193*	193*	0	0	201*	193*	Maximum concentration is above background. Maximum concentration is above piscivorous mammal and piscivorous bird NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Silver	0.0025[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Strontium	10.2	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.
Sulfate	14400	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Thallium	0.0005[b]	N/A	N/A	N/A	N/A	0	0	0	0	Maximum concentration equal to background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Uranium	5.12	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Vanadium	0.249	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.
Zinc	0.023	0	0	0	0	0	0	0	0	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.

[a]Analyte is estimated, based on laboratory qualifier.
[b]All analytes were below detection; maximum value based on one-half of detection limit.
[c]Analytes in data set represent multiple detection limits. This is the highest value in the data that was below its respective detection limit.
*Number of samples whose concentrations exceeded the corresponding wildlife toxicity benchmarks. Asterisks also identify contaminants retained as contaminants of potential concern

Aluminum. The maximum aluminum concentration was about 2 to 3 times the uppermost background value and exceeded by about 1 order of magnitude the food/water benchmarks, resulting in NOAELs for the river otter and mink (Table A2–4). A total of 17 sample values (excluding background) exceeded the river otter NOAEL-based food/water benchmark (Table A2–6). The maximum aluminum concentration exceeded slightly the food/water benchmarks resulting in LOAELs for the river otter and mink (Table A2–4), and only two sample values exceeded the river otter LOAEL-based food/water benchmark (Table A2–6).

Adverse effects would be unlikely to result from food/water consumption at these two sample locations, because the river otter and mink very likely consume food and water over a much larger area. The average aluminum concentration in the sampled area slightly exceeds the food/water benchmarks resulting in NOAELs for the river otter and is slightly less than the food/water benchmarks resulting in NOAELs for the mink (Table A2–4). Consequently, adverse effects would also be unlikely to result from food/water consumption over the entire sampled area. Thus, the potential impacts, if any, to piscivorous mammalian wildlife from exposure to aluminum in surface water would be small, and further assessment is not warranted.

The maximum aluminum concentration did not exceed either the avian drinking water or piscivorous bird food/water benchmarks. Thus, further assessment of avian exposure to aluminum in surface water is not warranted.

Ammonia. The maximum ammonia concentration was 4 to 5 orders of magnitude above background and the mean concentration (19.39 mg/L) was about 2 orders of magnitude above background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks (the only types of benchmarks that can be compared with contaminant concentrations in surface water) available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, most experimental toxicological work concerning the oral route of administration has centered on ammonium chloride (Arnold et al. 1997, Crookshank et al. 1973, Fukushima et al. 1986, Goldman and Yakovac 1964, Shibata et al. 1989). Few studies have attempted to identify the role of ammonia in the effects (World Health Organization 1986). Consequently, no benchmarks could be derived for ammonia using the methodology provided in Sample et al. (1996) due to the lack of other toxicological data in the literature. Further, EPA has not provided an oral reference dose factor (for humans) for ammonia (http://www.epa.gov/iris/subst/0422.htm#reforal), nor is there a human drinking water standard. The lack of toxicological data suggests that the occurrence of ammonia in food and drinking water is generally considered not to pose potentially significant toxic effects for terrestrial organisms. This precludes further screening of wildlife exposure to ammonia in surface water.

Cadmium. The maximum cadmium concentration was about 2 orders of magnitude above background and exceeded the food/water benchmarks that resulted in NOAELs for the river otter and mink by about 1 order of magnitude (Table A2–4). A total of eight sample values exceeded the river otter NOAEL-based food/water benchmark (Table A2–6). The maximum cadmium concentration was slightly greater than the food/water benchmarks that resulted in LOAELs for the river otter and slightly less than the food/water benchmarks that resulted in LOAELs for the mink (Table A2–4). No sample values other than the maximum exceeded the LOAEL-based river otter food/water benchmark (Table A2–6).

The maximum cadmium concentration exceeded by about 1 order of magnitude the food/water benchmark resulting in a NOAEL for the belted kingfisher and exceeded by about one-half an order of magnitude that of the osprey and great blue heron (Table A2–5). A total of eight sample values exceeded the belted kingfisher NOAEL-based food/water benchmark (Table A2–6). The maximum concentration exceeded only slightly the food/water benchmark resulting in a LOAEL for the belted kingfisher and was less than that of the osprey and great blue heron (Table A2–5). No sample values other than the maximum exceeded the LOAEL-based belted kingfisher food/water benchmark (Table A2–6).

Adverse effects to the river otter and belted kingfisher would be unlikely to result from food/water consumption at the location of the maximum sample value, because these species very likely consume food and water over a much larger area. The average cadmium concentration in the sampled area slightly exceeds the river otter and belted kingfisher NOAEL-based food/water benchmarks but does not exceed associated LOAEL-based food/water benchmarks (Tables A2–4 and A2–5). Consequently, adverse effects would also be unlikely to result from food/water consumption by these species over the entire sampled area. Thus, the potential impacts, if any, to piscivorous mammalian and avian wildlife from exposure to cadmium in surface water would be small, and further assessment is not warranted.

Chloride. The maximum chloride concentration was about 2 orders of magnitude above background concentration, and the mean concentration (255.08 mg/L) ranged from about 1.5 to 10 times background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for chloride using this methodology due to the lack of other toxicological data in the literature. Further, there is also no human drinking water standard for chloride. The lack of toxicological data suggests that the occurrence of chloride in drinking water is generally considered not to pose potentially significant toxic effects for terrestrial organisms (compounds that include chloride are likely to be more toxic to terrestrial organisms than chloride alone). This precludes further screening of wildlife exposure to chloride in surface water.

Iron. The August 2002 samples include some that were not filtered. In the state of Utah, only filtered samples should be used for comparison to benchmarks (UAC 2003). Thus, the unfiltered August 2002 samples were removed and only filtered iron samples (Tables A2–4 and A2–5) are used in this analysis.

The maximum and mean iron concentrations were about 2 orders and about 1 order of magnitude, respectively, above the highest background concentration (Table A2–4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent. Consequently, drinking water benchmarks were derived for the 9 mammal and 11 bird species listed above using the methodology provided in Sample et al. (1996). The derived NOAEL-based drinking water benchmarks were then used to derive food/water benchmarks for piscivorous mammals and birds. A brief outline of the methodology used for deriving drinking water benchmarks follows.

First, mammal and bird NOAELs were either obtained from the results of laboratory experiments summarized in the literature or estimated from acute toxicity benchmarks summarized in the literature. A mammalian NOAEL of 120 mg/kg/day, with mice as test organisms and weight loss

as the endpoint, was obtained from Parametrix (2001). Because an avian NOAEL was unavailable, an avian LD_{50} of greater than 4,500 mg/kg/day, with quail as the test organism and no endpoint specified, was used (Parametrix 2001). Because the precise avian LD_{50} was not specified but was given as being an unknown value greater than 4,500 mg/kg/day, 4,500 mg/kg/day was used to be conservative. No standardized mathematical relationship exists between an LD_{50} and a NOAEL (Sample et al. 1996). Exposure levels associated with NOAELs may range from 1/10 to 1/10,000 of the acutely toxic dose (Sample et al. 1996). Consequently, a high and a low NOAEL were estimated by applying these factors to the avian LD_{50}, resulting in high and low avian NOAELs of 450 and 0.45 mg/kg/day, respectively.

The literature-based mammalian and avian NOAELs were used to derive NOAELs for the 9 mammal and 11 bird species listed above by adjusting for differences in body weight (kg) between the test organism and target species (Sample et al. 1996). These derived NOAELs (mg/kg/day) were then used to derive drinking water equivalents (mg/L) using the body weight of the target species and its rate of water consumption (L/day) (Sample et al. 1996). The lowest mammal drinking water benchmark was for white-tailed deer (278 mg/L), 2 orders of magnitude above the maximum iron surface water concentration (3.08 mg/L) (Table A2–4). The lowest of the high and low avian drinking water benchmarks were for the rough-winged swallow (3,517 and 3.5 mg/L, respectively). These values were 3 orders of magnitude above and just slightly above the maximum iron surface water concentration (Table A2–4), respectively, and about 2 orders of magnitude above the mean concentration (0.098 mg/L) (Table A2–4). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of iron in surface water via drinking only. No further evaluation of wildlife exposure to iron in surface water via drinking is warranted.

The above derived NOAEL-based drinking water benchmarks were then used to derive NOAEL-based food/drinking water benchmarks for the two piscivorous mammals (mink and river otter) and three piscivorous birds (belted kingfisher, great blue heron, and osprey) using the body weight of the species, its rate of water and food (kg/day) consumption, and biological accumulation factor (BAF) (Sample et al. 1996). The BAF is the ratio of the concentration of a contaminant in tissue (mg/kg) to its concentration in water (mg/L), where both the organism and its prey are exposed, and is expressed as liters per kilogram. For most inorganic compounds, the BAF is assumed to equal the biological concentration factor (BCF). The BCF is the ratio of the concentration of a contaminant in food to its concentration in water (i.e., [mg/kg]/[mg/L] = L/kg) (Sample et al. 1996). A BAF of 200 reported for the edible parts of fish in a critical review of bioaccumulation factors in aquatic systems by Karlsson et al. (2002) was used in this analysis.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 18.18 mg/L for mink. The maximum iron concentration (3.08 mg/L) (Table A2-4) is about six times lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum iron concentration, piscivorous mammals would be unlikely to be adversely affected by consumption of iron in surface water and associated prey. No further evaluation of piscivorous mammal exposure to iron in surface water and associated prey is warranted.

The low NOAEL-based piscivorous bird food/drinking water benchmarks were 0.04 mg/L for the belted kingfisher, 0.13 mg/L for the osprey, and 0.15 mg/L for the great blue heron. The maximum iron concentration (3.08 mg/L) (Table A2-4) is about 2 orders of magnitude higher than the kingfisher benchmark, and about a factor of 20 higher than the osprey and heron benchmarks. However, since piscivorous birds would integrate their exposure by foraging over a

much larger area than the point where the maximum surface water concentration was taken, the average iron concentration is more applicable than the maximum. The average iron concentration (0.098 mg/L) (Table A2-4) is only about two times higher than the kingfisher benchmark and is slightly lower than the osprey and heron benchmarks.

Thus, the kingfisher is the only species of the three whose NOAEL-based food/drinking water benchmark was exceeded by the average iron concentration. However, it is exceedance of a LOAEL, not a NOAEL, that implies potential adverse effects. There is no LOAEL-based food/water benchmark for piscivorous bird species, and one cannot be derived because there is no standard relationship that applies when extrapolating from a NOAEL and a LOAEL (because the LOAEL is the point where adverse effects begin, and the NOAEL could be anywhere below it). Consequently, it is uncertain whether exceedance of the low kingfisher NOAEL-based food/drinking water benchmark by the average iron concentration could result in potential adverse effects. The following two discussion points serve to diminish such a possibility.

First, the high NOAEL-based food/drinking water benchmark for the belted kingfisher was 42.72 mg/L. The average iron concentration (0.098 mg/L) (Table A2-4) is about 2.5 orders of magnitude below this benchmark. Thus, in this case, adverse effects would be very unlikely. Second, the fact that the maximum iron concentration is suspect further diminishes the possibility of potential adverse effects under the low NOAEL-based food/drinking water benchmark, as follows.

The maximum iron concentration (3.08 mg/L) (Table A2–4) is somewhat anomalous in that it is the only sample that is 2 to 3 orders of magnitude above the rest of the values, including background. When this value is removed, the new maximum from the sampled area becomes 0.04 mg/L and the new mean (0.007 mg/L [N=33, SD=0.006]) is slightly less than the mean background concentration (0.012 mg/L [N=3, SD=0.005]). This new mean iron concentration is about 1 and 4 orders of magnitude below the low and high kingfisher food/drinking water benchmarks, respectively. In summary, potential adverse effects to the kingfisher from iron in surface water and associated prey appear unlikely, and further assessment of this species is not warranted.

Mercury. The maximum mercury concentration was about 2 orders of magnitude above background and exceeded by about 3 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the river otter and mink (Table A2–4).

The maximum mercury concentration exceeded by about 4 orders of magnitude the food/water benchmark resulting in a NOAEL for the belted kingfisher and exceeded by about 3 orders of magnitude the food/water benchmarks resulting in NOAELs for the osprey and great blue heron (Table A2–5). Further, the maximum mercury concentration exceeded by about 3 orders of magnitude the food/water benchmark resulting in a LOAEL for the belted kingfisher and exceeded by about 2 orders of magnitude the food/water benchmarks resulting in LOAELs for the osprey and great blue heron (Table A2–5).

Mercury was undetected in the rest of the mercury samples other than the maximum, including background, some of the samples had a detection limit of 0.0002 mg/L and the others had a detection limit of 0.0001 mg/L. Results of these samples in which mercury was undetected were assigned a value of one-half the corresponding detection limit. Eighty-five of these sample values (excluding background sample values) exceeded all the piscivorous mammal and bird

LOAEL-based food/water benchmarks (Table A2–6) by 1 to 2 orders of magnitude (Tables A2–4 and A2–5). The 15 background sample values similarly exceeded all the piscivorous mammal and bird LOAEL-based food/water benchmarks.

Adverse effects would be unlikely to result from food/water consumption at the location where the maximum mercury concentration was obtained, because the river otter, mink, belted kingfisher, osprey, and great blue heron very likely consume food and water over a much larger area. However, adverse effects to these species could potentially result if food/water consumption occurred largely within the sampled area, based on the above evaluation of samples in which mercury was undetected. Nonetheless, because the actual concentrations of mercury are unknown over most of the sampled area, further assessment is warranted. This might include analytical methods and instrumentation that provide lower detection limits.

Molybdenum. The maximum molybdenum concentration was about 3 orders of magnitude above the uppermost background value and was about 3 times greater than the drinking water benchmark resulting in a NOAEL for white-tailed deer (Table A2–4). A total of eight sample values exceeded the white-tailed deer NOAEL-based drinking water benchmark, but none, including the maximum, exceeded the associated LOAEL-based drinking water benchmark (Table A2–6). The maximum molybdenum concentration did not exceed the avian NOAEL- or LOAEL-based drinking water benchmarks (Table A2–5). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of molybdenum by drinking surface water, and further assessment is not warranted.

There are currently no published piscivorous wildlife food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Consequently, piscivorous mammal (mink and river otter) and bird (belted kingfisher, great blue heron, and osprey) food/water benchmarks were derived using the methodology provided in Sample et al. (1996). A brief outline of the methodology used for deriving these benchmarks follows.

First, piscivorous mammal and bird drinking water NOAELs were obtained from Sample et al. (1996). These drinking water NOAELs were used to derive the piscivorous mammal and bird food/water NOAELs using the species' body weight (kg), its rate of food (kg/day) and water (L/day) consumption, and BAF (Sample et al. 1996). A BAF of 10, with a 10-fold error likely according to other data, was reported for the edible parts of fish in a critical review of BAFs in aquatic systems by Karlsson et al. (2002). Consequently, three food/drinking water NOAELs were derived for each piscivorous mammal and bird species, one for each BAF of 1, 10, and 100.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 0.08 mg/L for mink, derived using a BAF of 100. The maximum molybdenum concentration (1.91 mg/L) (Table A2-4) is more than 1 order of magnitude higher than this benchmark. However, since piscivorous mammals would integrate their exposure by foraging over a much larger area than the point where the maximum surface water concentration was detected, the average molybdenum concentration is more applicable. The average molybdenum concentration (0.05 mg/L) (Table A2-4) is slightly less than this benchmark. Consequently, since this derived NOAEL was not exceeded by the average molybdenum concentration, piscivorous mammals would not likely be adversely affected by consumption of molybdenum in surface water and associated prey.

The lowest NOAEL-based piscivorous bird food/drinking water benchmark was 0.64 mg/L for belted kingfisher, derived using a BAF of 100. The maximum molybdenum concentration (1.91 mg/L) (Table A2-4) is about three times higher than this benchmark. However, since piscivorous birds would integrate their exposure by foraging over a much larger area than the point where the maximum surface water concentration was detected, the average molybdenum concentration is more applicable. The average molybdenum concentration (0.05 mg/L) (Table A2-4) is about 1 order of magnitude below this benchmark. Consequently, since this derived NOAEL was not exceeded by the average molybdenum concentration, piscivorous birds would not likely be adversely affected by consumption of molybdenum in surface water and associated prey.

Further assessment of piscivorous avian and mammalian exposure to molybdenum in surface and associated prey is not warranted.

Nitrate. The maximum nitrate concentration was about 4 times the maximum background concentration (Table A2–4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for nitrate using this methodology due to the lack of other toxicological data in the literature.

Consequently, drinking water standards for livestock were used. Guidelines for levels of nitrate in drinking water for livestock are as follows: 0 to 440 mg/L is considered safe; 440 to 1,300 mg/L is a cautionary level where the additive effect of nitrate in feed should also be considered; and over 1,300 mg/L is considered potentially toxic (Bagley et al. 1997). The maximum nitrate concentration (Table A2–4) falls near the bottom of the range of values considered safe for livestock. Thus, based on livestock drinking water standards, further assessment of wildlife exposure to nitrate in surface water is not warranted.

Selenium. The maximum selenium concentration was about 1 order of magnitude above background and exceeded by about 2 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the river otter and mink (Table A2–4). The maximum selenium concentration exceeded by about 1 to 2 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the belted kingfisher, osprey, and great blue heron (Table A2–5). The mean selenium concentration exceeded the river otter and mink NOAEL and LOAEL food/water benchmarks by 1 order of magnitude (Table A2–4), and the belted kingfisher, osprey, and great blue heron NOAEL and LOAEL food/water benchmarks by 1 order of magnitude or less (Table A2–5).

Thus, adverse effects to these species would be unlikely to result from food/water consumption at the location where the maximum selenium concentration was obtained because they would not obtain all their food/water from one location. However, adverse effects could potentially result from the mean selenium concentration if food/water consumption occurred largely within the sampled area. However, the mean selenium concentration (0.00446 mg/L [N=193, SD=0.0026]) in this area is virtually the same as the mean background concentration (0.00441 mg/L [N=15, SD=0.0021]). Thus, any adverse effects may not be attributable to the Moab site. Nevertheless, two samples (0.012 and 0.014 mg/L) from the contaminated portion of the river have selenium concentrations that are greater than two standard deviations above the mean (Table A2–4), and one sample concentration (0.026 mg/L) is greater than eight standard

deviations above the mean. These three samples were all collected on April 12, 2000, and there is no detection limit reported for them. Because of the uncertainty surrounding these high values and the associated potential for adverse effects to piscivorous mammals and birds at the three locations where they were obtained, further assessment is warranted.

Silver. Silver was undetected in all of the samples, and various silver detection limits were associated with the samples. The maximum silver detection limit (0.005 mg/L) was associated with only one sample, and it was higher than the maximum background silver detection limit (0.0001 mg/L) by a factor of 50 (Table A2–4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Consequently, as was done above for iron, drinking water benchmarks were derived for 9 mammal and 11 bird species using the methodology provided in Sample et al. (1996). The derived NOAEL-based drinking water benchmarks were then used to derive food/water benchmarks for piscivorous mammals and birds. A brief outline of the methodology used for deriving drinking water benchmarks follows.

First, mammal and bird NOAELs were either obtained from the results of laboratory experiments summarized in the literature or estimated from acute toxicity benchmarks summarized in the literature. A mammalian NOAEL of 222.2 mg/kg/day, with rats as test organisms and weight loss as the endpoint, was obtained from Ratte (1999) and Parametrix (2001). Because an avian NOAEL was unavailable, an avian LD_{50} of greater than 4,500 mg/kg/day, with quail as the test organism and no endpoint specified, was used (Parametrix 2001). Because the precise avian LD_{50} was not specified but was given as being an unknown value greater than 4,500 mg/kg/day, 4,500 mg/kg/day was used to be conservative. No standardized mathematical relationship exists between an LD_{50} and a NOAEL (Sample et al. 1996). Exposure levels associated with NOAELs may range from 1/10 to 1/10,000 of the acutely toxic dose (Sample et al. 1996). Consequently, a high and a low NOAEL were estimated by applying these factors to the avian LD_{50}, resulting in high and low avian NOAELs of 450 and 0.45 mg/kg/day, respectively.

The literature-based mammalian and avian NOAELs were used to derive NOAELs for the 9 mammal and 11 bird species listed above by adjusting for differences in body weight (kg) between the test organism and target species (Sample et al. 1996). These derived NOAELs (mg/kg/day) were then used to derive drinking water equivalents (mg/L) using the body weight of the target species and its rate of water consumption (L/day) (Sample et al. 1996). The lowest mammal drinking water benchmark was for white-tailed deer (952 mg/L), at least 5 orders of magnitude above the maximum silver detection limit (0.005 mg/L) (Table A2−4). The lowest of the high and low avian drinking water benchmarks were for the rough-winged swallow (3,517 and 3.5 mg/L, respectively). These values were between 5 and 6 and between 2 and 3 orders of magnitude, respectively, above the maximum silver detection limit (0.005 mg/L) (Table A2−4). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of silver in surface water via drinking alone. No further evaluation of wildlife exposure to silver in surface water via drinking is warranted.

The above derived NOAEL-based drinking water benchmarks were then used to derive NOAEL-based food/drinking water benchmarks for the two piscivorous mammals (mink and river otter) and three piscivorous birds (belted kingfisher, great blue heron, and osprey) listed using the body weight of the species, its rate of water and food (kg/day) consumption, and BAF (Sample et al. 1996). Two BAFs of 5 and 10, each with a 10-fold error likely according to other data, were reported for the edible parts of fish in a critical review of BAFs in aquatic systems by Karlsson et al. (2002). Consequently, five food/drinking water NOAELs were derived for each piscivorous mammal and bird species, one for each BAF of 0.5, 1, 5, 10, and 100.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 123.97 mg/L for mink. The maximum silver detection limit (0.005 mg/L) (Table A2–4) is about 4 orders of magnitude lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum silver detection limit, piscivorous mammals would be unlikely to be adversely affected by consumption of silver in surface water and associated prey. No further evaluation of piscivorous mammal exposure to silver in surface water and associated prey is warranted.

The lowest of the low NOAEL-based piscivorous bird food/drinking water benchmarks was 0.09 mg/L for the belted kingfisher. The maximum silver detection limit (0.005 mg/L) (Table A2–4) is about 1 order of magnitude lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum silver detection limit, piscivorous birds would be unlikely to be adversely affected by consumption of silver in surface water and associated prey. No further evaluation of piscivorous bird exposure to silver in surface water and associated prey is warranted.

Sulfate. The maximum sulfate concentration was about 2 orders of magnitude above background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for sulfate using this methodology due to the lack of other toxicological data in the literature.

Consequently, drinking water standards for livestock were used. Guidelines for levels of sulfate in drinking water for livestock are as follows. Sulfate levels up to 1,500 mg/L produce slight effects on livestock (objectionable taste); levels from 1,500 to 2,500 mg/L produce temporary diarrhea; and levels above 4,500 mg/L should not be used (Bagley et al. 1997).

The maximum sulfate concentration (Table A2–4) is about 3 times this maximum level (4,500 mg/L). Wildlife species would likely consume their water over a much broader area than from the location where the maximum sulfate sample was obtained. Thus, any effects would more likely be incurred by water consumption over the entire sampled area. The mean sulfate concentration (609.65 mg/L) in the sampled area could therefore produce slight effects on wildlife, based on the above guidance. This precludes further screening of wildlife exposure to sulfate in surface water. (Note that compounds that include sulfate are likely to be more toxic to terrestrial organisms than sulfate alone).

Summary of Chemical Impacts to Wildlife. From the 28 original contaminants, 11 preliminary contaminants of potential concern (aluminum, ammonia, cadmium, chloride, iron, mercury, molybdenum, nitrate, selenium, silver, and sulfate) were selected for further assessment. From

these, nine were excluded and two potential contaminants of concern were selected: mercury and selenium. These two were selected because they could potentially cause chronic adverse effects to piscivorous mammalian and avian species consuming food/water within the surface waters of the nearshore environment within the contaminated portion of the river.

Chemical Impacts to Plants. Plants may be exposed to contaminants via root or dermal uptake of contaminants. Of these, root uptake would likely be the primary exposure pathway. Soil contaminant data were available for only a limited area of the Moab site, at some temporary monitoring wells just northeast of the tailings pile. The soil samples were taken at a depth of from 0 to 1 ft at these locations (DOE 2003). It is currently estimated that 309 acres of contaminated soils at an average depth of from 12 to 18 inches would be removed (under the on-site and off-site disposal alternatives) from the Moab site and be replaced with 6 inches of borrowed reclamation soil. Thus, the sampled soil layer would be excluded as a source of potential impacts to plants, which themselves would be absent until the site was revegetated or otherwise recolonized following reclamation. Consequently, the existing soil contaminant data were not used to evaluate chemical impacts to plants. Instead, contaminants in the freshwater aquifer were used because they were considered more representative of the entire Moab site and because they will remain as a source of potential impacts to plants much longer than the top layer of soil.

Only root uptake is considered, since only phytotoxicity benchmarks based on root uptake were available. Maximum and mean concentrations of contaminants in the freshwater aquifer were obtained from Chapter 5.0 of the SOWP (DOE 2003) and screened based on their exceedance of available phytotoxicity benchmarks (Table A2–7). Soil solution phytotoxicity benchmarks were available only for the metals (Efroymson et al. 1997).

The following nine metals had maximum concentrations that exceeded maximum background concentrations and were slightly less than or exceeded phytoxicity benchmarks: aluminum, arsenic, cobalt, copper, iron, manganese, mercury, molybdenum, and vanadium (Table A2–7). Four of these metals had mean concentrations that were slightly below or above phytotoxicity benchmarks: arsenic, manganese, molybdenum, and vanadium. These nine metals, but particularly the latter four, could cause phytotoxic effects, assuming that plants had root access to the freshwater aquifer or associated soil water above it. In addition, these metals could become translocated to plant parts consumed by herbivorous wildlife or by terrestrial invertebrates that are in turn consumed by wildlife. Consequently, these metals could potentially cause toxic effects to wildlife. However, the nature and extent of such effects, if any, are unknown.

Radiological Impacts to Wildlife and Plants. Samples of radioactive constituents in surface water were collected by SMI, DOE, and the USGS between 2000 and 2002. Of the 10 radioactive contaminants sampled (excluding gross alpha and gross beta), 3 are evaluated here (uranium-238, uranium-234, and radium-226), since only these were included in the library of constituents of the RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) (DOE 2002) used in this evaluation.

The RESRAD Biota Code was used to screen the radiological dose rate to generic (not species-specific) riparian animals and generic terrestrial plants based on the maximum observed concentrations of uranium-238, uranium-234, and radium-226 in surface water. The total radiological dose was estimated using the default parameters (e.g., BAFs) provided in the RESRAD Biota Code, since such site-specific data were lacking.

The total estimated radiological dose was divided by the applicable DOE dose limits or standards designed to protect the terrestrial (including riparian) environment, including populations of animals and plants. These dose limits or standards are 0.1 rad/day for terrestrial (including riparian) animals and 1 rad/day for terrestrial (including riparian) plants (DOE 2002). A quotient greater than 1 indicates exceedence of such a dose limit or standard and thus a potential risk of radiotoxic effects. Where a quotient exceeded 1, the RESRAD Biota Code was used to screen the dose rate based on the mean observed concentrations of uranium-238, uranium-234, and radium-226, since vertebrates integrate their exposure over a much larger area than the location from which the maximum concentration was obtained. Input maximum and mean concentrations and the corresponding quotients are provided in Table A2–8.

Table A2–7. Background Range and On-Site and Downgradient Range and Mean Concentrations of Metals in the Freshwater Aquifer and Soil Solution Phytotoxicity Benchmarks

Constituent	Background Range (mg/L)	On-Site and Downgradient Range (mg/L)	On-Site and Downgradient Mean (mg/L)	Soil Solution Phytotoxicity Benchmark (mg/L)
Aluminum	<0.0076–<0.051	0.002–0.29	0.0207	0.3
Antimony	<0.0001–<0.011	<0.0001–<0.0029	0.000534	N/A[a]
Arsenic	0.00018–0.0015	<0.0001–0.361	0.0109	0.001
Barium	0.0222–0.033	<0.01–0.108	0.0362	N/A
Beryllium	0.002–0.002	<0.001–0.0021	0.000775	0.5
Bismuth	<0.011–<0.011	<0.001–<0.011	0.00158	20
Cadmium	<0.0001–<0.0017	<0.0001–0.0208	0.0018	0.1
Chromium	<0.0005–<0.011	<0.0005–<0.003	0.000638	0.05
Cobalt	<0.0013–0.002	0.00055–0.064	0.00755	0.06
Copper	<0.0004–0.005	<0.0004–0.068	0.0102	0.06
Iron	<0.0008–<0.05	<0.0008–17.1	1.28	10
Lead	<0.0001–<0.0055	<0.0001–<0.0055	0.000355	0.02
Lithium	0.0278–1	0.0201–1.71	0.373	3
Manganese	<0.0001–0.0157	<0.01–14.5	3.1	4
Mercury	<0.0001–<0.0002	<0.0001–0.003	0.000488	0.005
Molybdenum	<0.0018–0.01	<0.001–10.8	0.844	0.5
Nickel	<0.0006–0.015	<0.0006–0.089	0.0185	0.5
Selenium	0.0091–0.0266	<0.0001–0.205	0.032	0.7
Silver	<0.0001–<0.0055	<0.0001–<0.0055	0.000309	0.1
Thallium	<0.0001–<0.011	<0.0001–<0.011	0.000451	0.05
Uranium	0.0042–0.0259	<0.0001–23.3	2.76	40
Vanadium	0.00061–0.0164	<0.0003–7.1	0.154	0.2
Zinc	<0.0006–0.011	<0.0006–0.16	0.0129	0.4

N/A = not available.

Table A2–8. Maximum and Mean Concentrations of Radioactive Constituents Evaluated Using the RESRAD Biota Code and Corresponding Quotients

Constituent	Maximum Concentration (pCi/L)	Riparian Animal Quotient	Riparian Plant Quotient	Mean Concentration (pCi/L)	Riparian Animal Quotient	Riparian Plant Quotient
Uranium-238	413			28.7		
Uranium-234	396	1.4	9.87E-06	29.5	1.3E-01	[a]
Radium-226	1.27			0.21		

[a]The terrestrial plant quotient was not calculated for the mean concentrations of the radionuclide constituents, since the terrestrial plant quotient calculated for the maximum concentrations did not exceed 1.

The quotient of riparian plants based on maximum surface water concentrations was 6 orders of magnitude below 1 (Table A2–8). The quotient for riparian animals based on maximum concentrations slightly exceeded 1 and thus could be of minor concern if riparian organisms were to get all their exposure at the location where the maximum sample was taken. However, riparian vertebrates integrate their exposure over a much larger area, and the quotient for riparian animals based on mean concentrations was about 1 order of magnitude below 1 (Table A2–8). Consequently, there is no potential risk of radiotoxic effects for either riparian vertebrates or plants from these radiological constituents in surface water.

A2–3.0 References

67 FR 77969, U.S. Department of Energy, "Notice of Intent To Prepare an Environmental Impact Statement and to Conduct Public Scoping Meetings, and Notice of Floodplain and Wetlands Involvement for Remediation of the Moab Uranium Mill Tailings Site in Grand County, UT," *Federal Register*, Vol. 67, No. 245, December 20, 2002.

Arnold, L.L., W.R. Christenson, M. Cano, M.K. St. John, B.S. Wahle, and S.M. Cohen, 1997. "Tributyl Phosphate Effects on Urine and Bladder Epithelium in Male Sprague-Dawley Rats," in *Fundamental and Applied Toxicology*, 40:247–255.

Barceloux, D.G., 1999. "Vanadium," in *Journal of Toxicology—Clinical Toxicology*, 37(2):265–278.

Bagley, C.V., J. Kotuby-Amacher, and K. Farrell-Poe, 1997. *Analysis of Water Quality for Livestock,* Utah State University Extension – Animal Fact Sheet, available at http://extension.usu.edu/files/agpubs/beef28.pdf.

Bosshard E.B, B. Zimmerli, and C. Schlatter, 1992. "Uranium in the Diet: Risk Assessment of its Nephro- and Radiotoxicity," in *Chemosphere*, 24(3):309–321.

Buhl, K.J., and S.J. Hamilton, 1996. "Toxicity of Inorganic Contaminants, Individually and in Environmental Mixtures, to Three Endangered Fishes (Colorado Squawfish, Bonytail, and Razorback Sucker)," in *Archives of Environmental Contamination and Toxicology*, 30:84–92.

Buttner, J.K., R.W. Soderberg, and D.E. Terlizzi, 1993. "An Introduction to Water Chemistry in Freshwater Aquaculture," Northeastern Regional Aquaculture Center (NRAC) Fact Sheet No. 170, North Dartmouth, Massachusetts, available at: http://darc.cms.udel.edu/AquaPrimer/wqchemntronrac170.pdf.

Cleveland, L., E.E. Little, D.R. Buckler, and R.H. Wiedmeyer, 1993. "Toxicity and bioaccumulation of waterborne and dietary selenium in juvenile bluegill (*Lepomis macrochirus*)," in *Aquatic Toxicology*, 27:265–280.

Cooley, H.M., and J.F. Klaverkamp, 2000. "Accumulation and Distribution of Dietary Uranium in Lake Whitefish (*Coregonus clupeaformis*)," in *Aquatic Toxicology*, 48:477–494.

Cooley, H. M., R.E. Evans, and J.F. Klaverkamp, 2000. "Toxicology of Dietary Uranium in Lake Whitefish (*Coregonus clupeaformis*)," in *Aquatic Toxicology*, 48:495–515.

Crookshank, H.R., H.E. Smalley, D. Furr, and G.F. Ellis Jr., 1973. "Ammonium Chloride and Ammonium Sulfate in Cattle Feedlot Finishing Rations," in *Journal of Animal Science*, 36(6):1007–1009.

DOE (U.S. Department of Energy), 2002. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE-STD-1153-2002, U.S. Department of Energy, Washington, D.C., July.

DOE (U.S. Department of Energy), 2003. *Site Observational Work Plan for the Moab, Utah, Site*, GJO-2003-424-TAC, U.S. Department of Energy, Grand Junction, Colorado, December.

Driver, C.J., 1994. *Ecotoxicity Literature Review of Selected Hanford Contaminants*, PNL-9394, Pacific Northwest National Laboratory, Richland, Washington.

EBI (Environmental Bureau of Investigation), 2003. "Nickel," Energy Probe Research Foundation, Toronto, Ontario, Canada, available at: http://www.e-b-i.net/ebi/contaminants/nickel.html.

Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants*, 1997 Revision, ES/ER/TM-85/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

EPA (U.S. Environmental Protection Agency), 1999. *1999 Update of Ambient Water Quality Criteria for Ammonia*, EPA-822-R99-014, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C.

EPA (U.S. Environmental Protection Agency), 2001a. *ECO Update: The role of screening-level risk assessments and refining contaminants of concern in baseline ecological risk assessments*, Publication 9345.0-14, EPA 540/F-01/014, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

EPA (U.S. Environmental Protection Agency), 2001b. *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim*, EPA/540/R/99/005, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA (U.S. Environmental Protection Agency), 2001c. *2001 Update of Ambient Water Quality Criteria for Cadmium*, EPA-822-R-01-001, U.S. Environmental Protection Agency, Office of Water, Washington, D.C, available at: http://www.epa.gov/waterscience/criteria/aqualife/cadmium/cad2001upd.pdf.

EPA (U.S. Environmental Protection Agency), 2002. *National Recommended Water Quality Criteria: 2002*, EPA-822-R-02-047, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C., available at: http://www.epa.gov/waterscience/pc/revcom.pdf.

EPA (U.S. Environmental Protection Agency), 2003. *Information on the Toxic Effects of Various Chemicals and Groups of Chemicals*, U.S. Environmental Protection Agency, Region 5, Chicago, Illinois, available at:
http://www.epa.gov/region5/superfund/eco/html/toxprofiles.htm.

Fukushima, S., M. Shibata, T. Shirai, S. Tamano, and N. Ito, 1986. "Roles of Urinary Sodium Ion Concentration and pH in Promotion by Ascorbic Acid of Urinary Bladder Carcinogenesis in Rats," in *Cancer Research*, 46:1623–1626.

Goldman, A.S. and W.C. Yakovac, 1964. "Salicylate Intoxication and Congenital Anomalies," in *Archives of Environmental Health*, 8:648–656.

Hamilton, S. J., 1995. "Hazard Assessment of Inorganics to Three Endangered Fish in the Green River, Utah," in *Ecotoxicology and Environmental Safety*, 30:134–142.

Hamilton S.J., R.T. Muth, B. Waddell and T.W. May, 2000. "Hazard Assessment of Selenium and Other Trace Elements in Wild Larval Razorback Sucker from the Green River, Utah," in *Ecotoxicology and Environmental Safety*, 45:132–147.

Hoffman, D.J., B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., 1995. *Handbook of Ecotoxicology*, CRC Press, Boca Raton, Florida.

Holdway, D.A., 1992. "Uranium toxicity to two species of Australian tropical fish," in *The Science of the Total Environment*, 125:137–158.

Hope, B., C. Loy, and P. Miller, 1996. "Uptake and Trophic Transfer of Barium in a Terrestrial Ecosystem," in *Bulletin of Environmental Contamination and Toxicology*, 56:683–689.

INEEL (Idaho National Engineering and Environmental Laboratory), 2001, "Gross Alpha Radiation", INEEL Environmental Surveillance, Education and Research Program, available at: http://www.stoller-eser.com/FactSheet/alpha.htm.

Karlsson, S., M. Meili, and U. Bergstroem, 2002. "Bioaccumulation Factors in Aquatic Systems: a Critical Review," Svensk Kaernbraenslehantering AB (Swedish Nuclear Fuel and Waste Management Co.), R-02-36, July.

Lemly, A.D., 1998. "Pathology of Selenium Poisoning in Fish," in *Environmental Chemistry of Selenium*, W.T. Frankenberger, and R.A. Engberb, New York, New York, Marcel Dekker, 281–296.

Loewengart, G., 2001. "Toxicity of Boron to Rainbow Trout: A Weight-of-the-Evidence Assessment," in *Environmental Toxicology and Chemistry*, 20(4):796–803.

Magos, L.M., and T. Suzuki, 1996. *Toxicology of Metals*, CRC Press, Boca Raton, Florida.

NRC (U.S. Nuclear Regulatory Commission), 1999. *Final Environmental Impact Statement Related to Reclamation of the Uranium Mill Tailings at the Atlas Site, Moab, Utah*, NUREG-1531, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, Washington, D.C., March.

Parametrix, 2001. Ecological Screening-Level Risk Assessment of the Lower Ottawa River, prepared for Limno-Tech, Inc., Ann Arbor, Michigan, by Parametrix, Kirkland, Washington.

Peterson, J., M. MacDonnell, L. Haroun, F. Monette, and R.D. Hildebrand, 2002. "Summary of Fact Sheets for Selected Environmental Contaminants to Support Health Risk Analyses," Argonne National Laboratory, Argonne, Illinois.

Pimentel, R., and R.V. Bulkley, 1983. "Concentrations of Total Dissolved Solids Preferred or Avoided by Endangered Colorado River Fishes," in *Transactions of the American Fisheries Society*, 112:595–600.

Rand, G.M., and S.R. Petrocelli, 1985. *Fundamentals of Aquatic Toxicology: Methods and Applications*, Hemisphere Publishing Corporation, Washington, D.C.

Ratte, H.T., 1999. "Bioaccumulation and Toxicity of Silver Compounds: a Review," in *Environmental Toxicology and Chemistry,* 18(1):89–108.

Reid, S.D., 2002. "Physiological Impact of Acute Molybdenum Exposure in Juvenile Kokanee Salmon (*Oncorhynchus nerka*)," in *Comparative Biochemical and Physiology*, Part C(133):355–367.

Reimer, P.S., 1999. *Environmental Effects of Manganese and Proposed Freshwater Guidelines to Protect Aquatic Life in British Columbia*, M.S. thesis, Department of Chemical and Bio-Resource Engineering, University of British Columbia, Vancouver, British Columbia, Canada.

Sample, B. E., D.M. Opresko, and G.W. Suter, 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*, ES/ER/TM-86/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Shibata, M.A., S. Tamano, Y. Kurata, A. Hagiwara, and S. Fukushima, 1989. "Participation of Urinary NA+, K+, pH, and L-Ascorbic Acid in the Proliferative Response of the Bladder Epithelium after the Oral Administration of Various Salts and/or Ascorbic Acid to Rats," in *Food and Chemical Toxicology*, 27(6):403–413.

Srivastava, A. K., and S.J. Agrawal, 1983. "Changes Induced by Manganese in Fish Testis," in *Experientia*, 39:1309–1310.

Stoller, 2002. "Quarterly Sampling Efforts at the Moab site," personal communication, letter from T. Wright, Stoller, to J. Berwick, U.S. Department of Energy, Grand Junction, Colorado, August 7, 2002.

Stubblefield, W.A., S.F. Brinkman, P.H. Davies, T.D. Garrison, J.R. Hockett, and M.W. McIntyre, 1997. "Effects of Water Hardness of the Toxicity of Manganese to Developing Brown Trout (*Salmo trutta*)," in *Environmental Toxicology and Chemistry*, 16(10):2082–2089.

Suter, G.W., and C.L. Tsao, 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota*, 1996 revision, ES/ER/TM-96/R2, Lockheed Martin Energy Systems, Inc. Oak Ridge, Tennessee, available at: http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf.

Swanson, S.M., 1983. "Levels of ^{226}Ra, ^{210}Pb and ^{total}U in Fish Near a Saskatchewan Uranium Mine and Mill," in *Health Physics*, 45(1):67–80.

Swanson S.M., 1985. "Food-chain transfer of U-series Radionuclides in a Northern Saskatchewan Aquatic System," in *Health Physics*, 49(5):747–770.

UAC (Utah Administrative Code), 2003. "Standards of Quality for Waters of the State," Utah Division of Administrative Rules, Rule R317-2, effective December 1, 2003, available at: http://www.rules.utah.gov/publicat/code/r317/r317-002.htm.

USGS (U.S. Geological Survey), 2002. *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah*, final report, U.S. Fish and Wildlife Service, Division of Environmental Quality, Off-Refuge Contaminant Assessment Program, Salt Lake City, Utah, December.

Waite, D.T., S.R. Joshi, and H. Sommerstad, 1988. "The Effect of Uranium Mine Tailings on Radionuclide Concentrations in Langley Bay, Saskatchewan, Canada," in *Archives of Environmental Contamination and Toxicology*, 17:373–380.

Wedemeyer, G. A., F.P. Meyer, and L. Smith, 1976. *Diseases of Fishes*, T.F.H. Publications, Neptune City, New Jersey.

Wicklund, A., L. Norrgren, and P. Runn, 1990. The Influence of Cadmium and Zinc on Cadmium Turnover in the Zebrafish, *Brachydanio rerio*," in *Archives of Environmental Contamination and Toxicology*, 19:348–353.

World Health Organization, 1986. World Health Organization International Programme on Chemical Safety (IPCS): Environmental Health Criteria 54 Ammonia.

Wrenn, M.E., P.W. Durbin, B. Howard, J. Lipsztein, J. Rundo, E.T. Still, and D.L. Willis, 1985. "Metabolism of Ingested U and Ra," in *Health Physics*, 48(5):601–633.